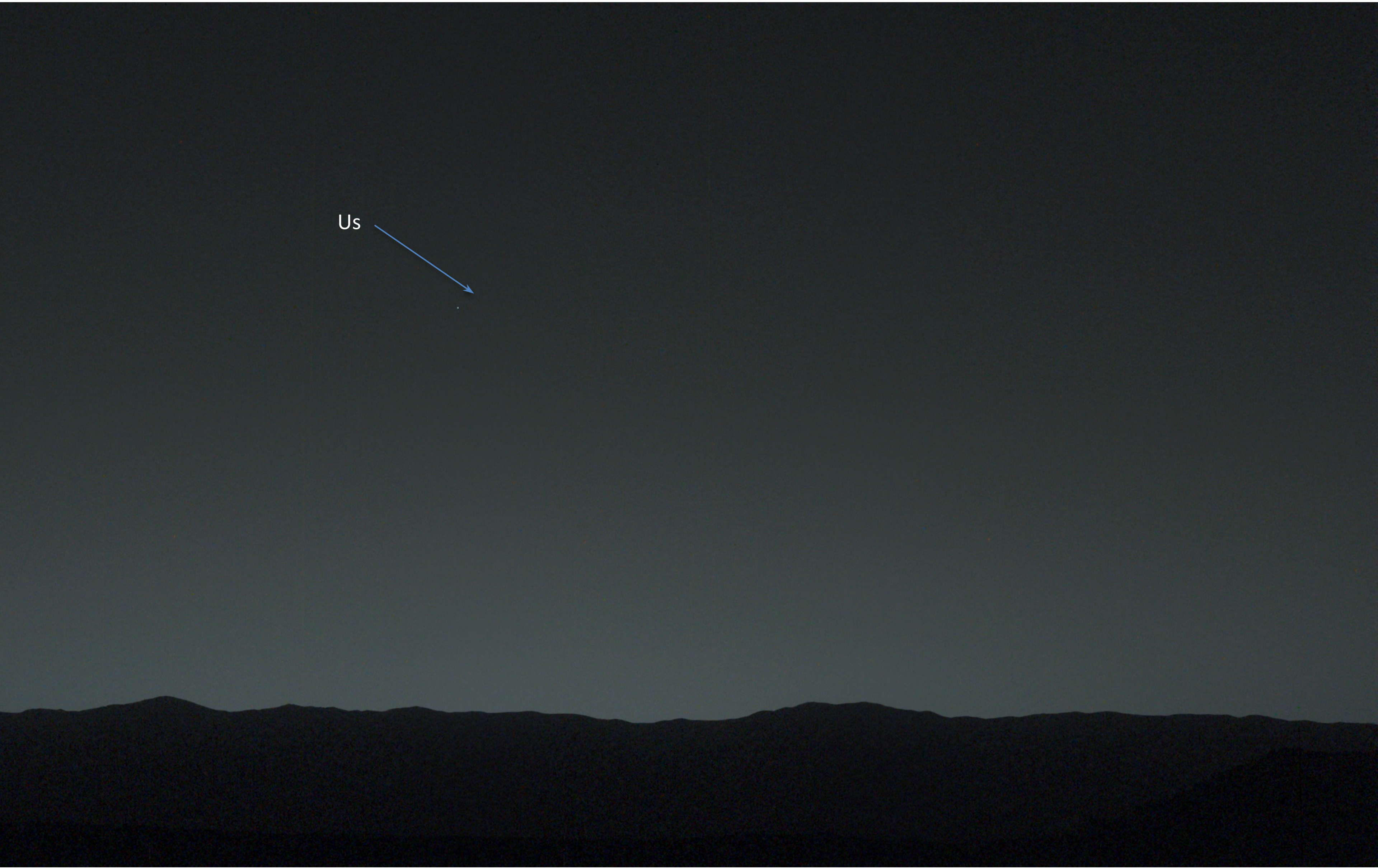
Exploring MARS with Rovers: MSL and what is M2020

Presented by M de la Torre, Work by Curiosity's ENV science team & M2020 team



Visiting Mars since 1976

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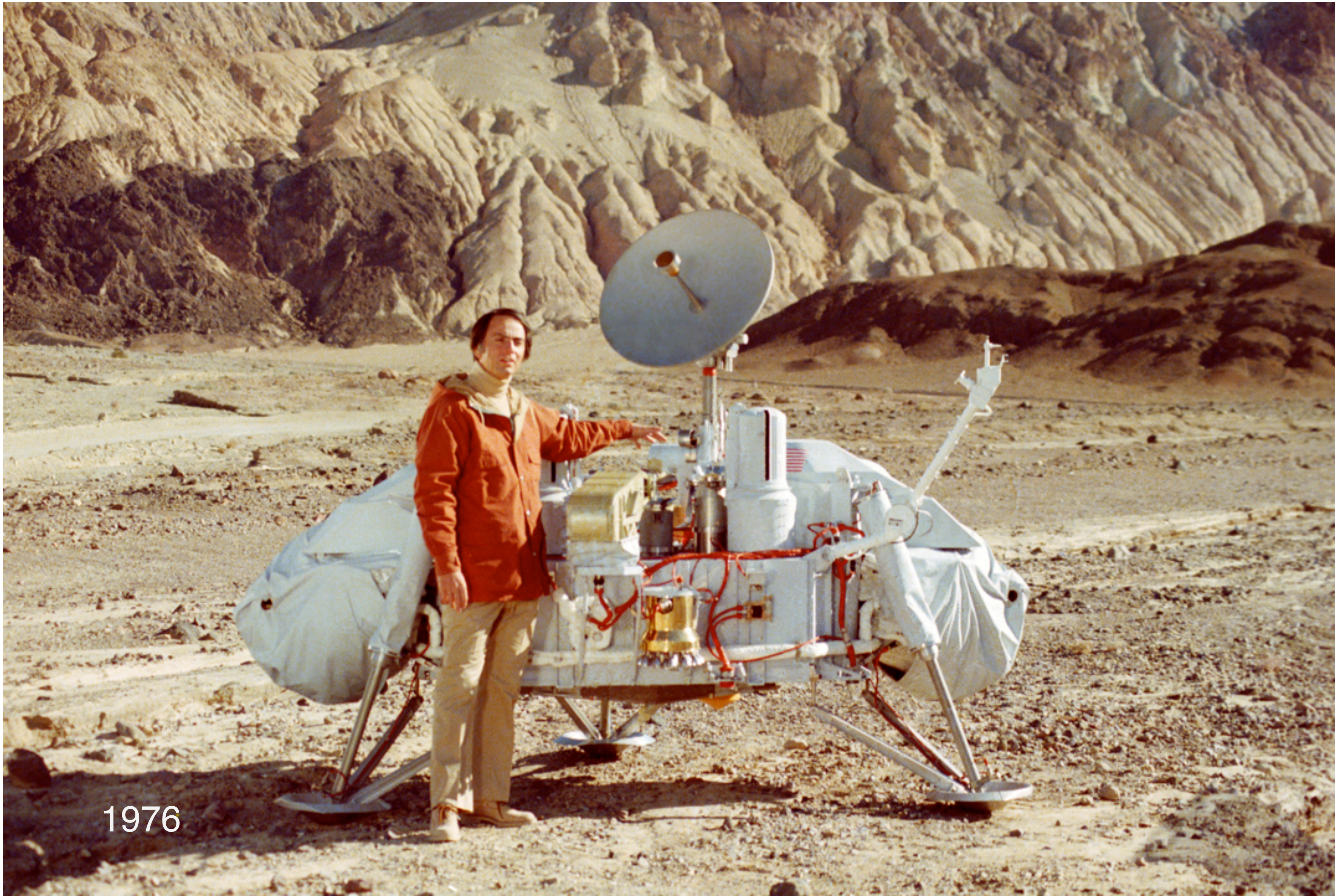

Missions to Mars since 2001

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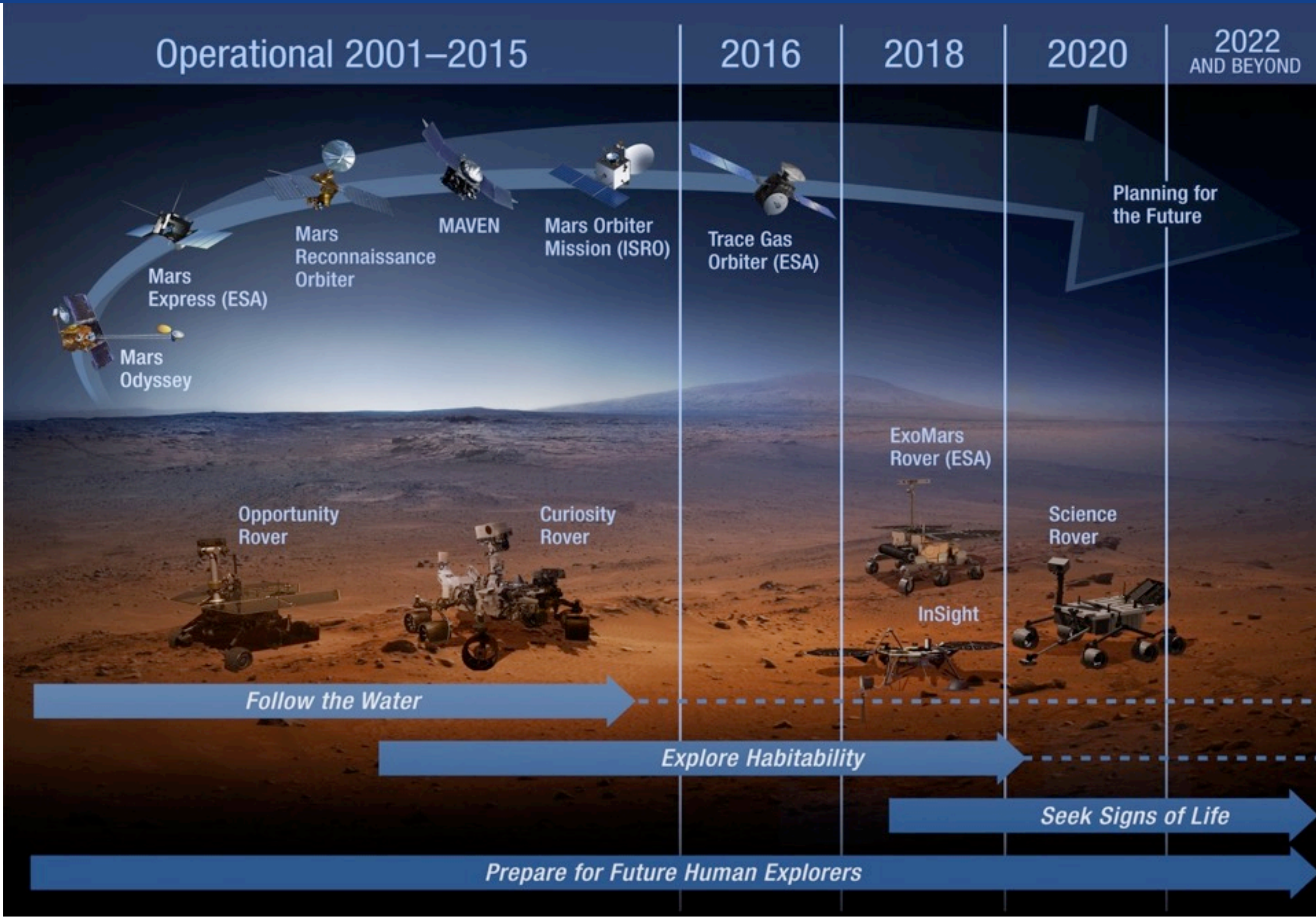

Four driving Mars science goals

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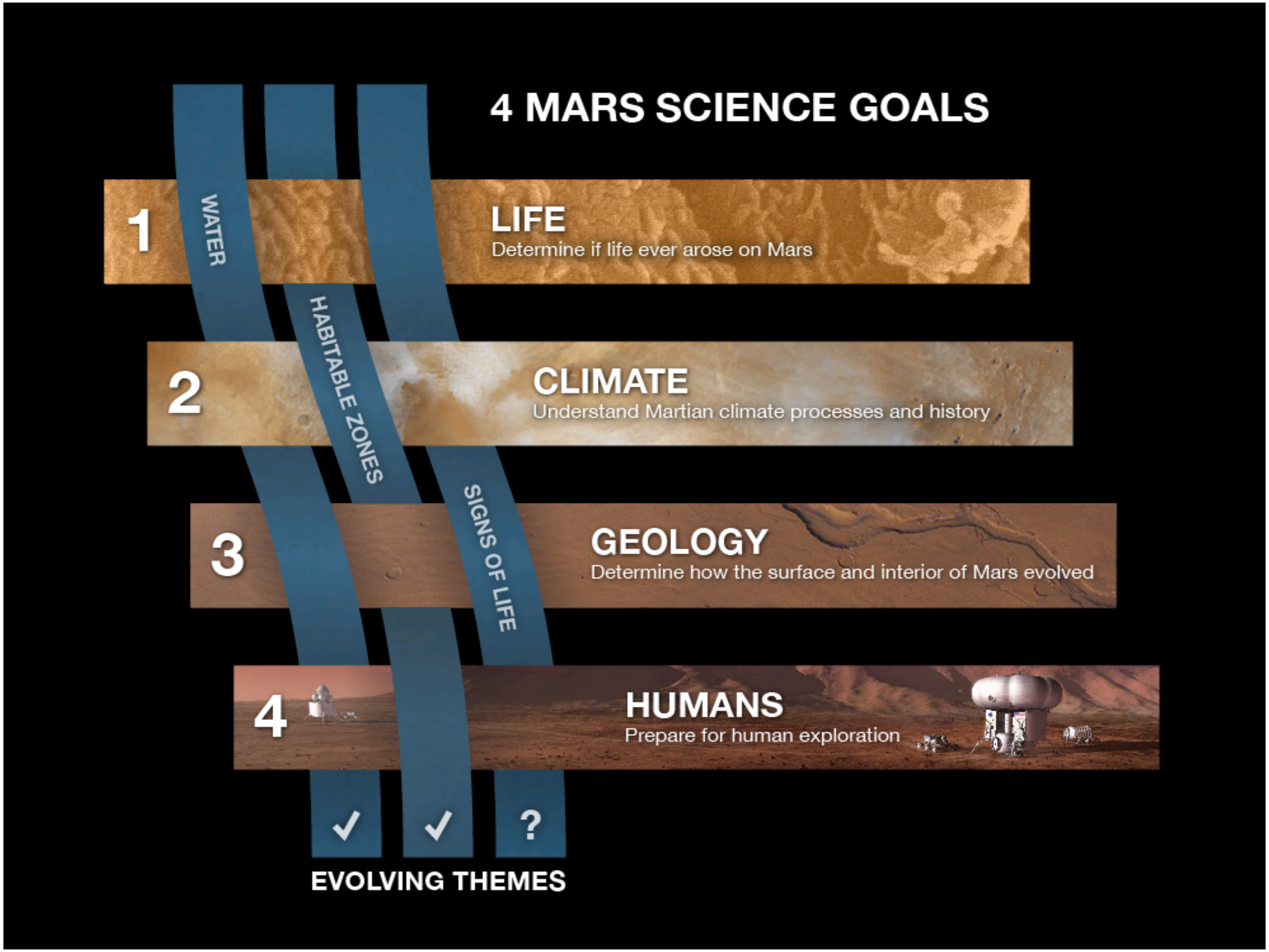
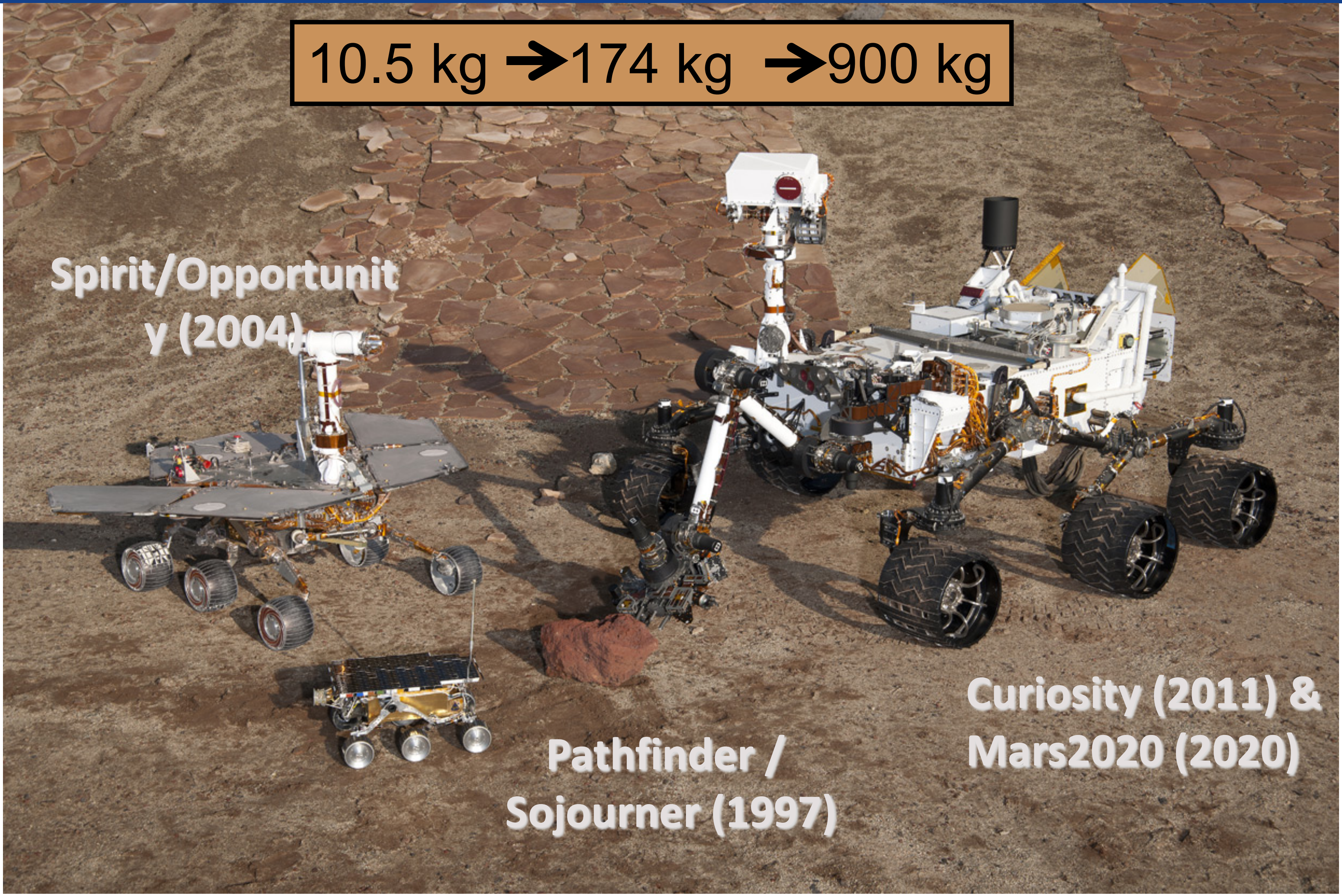
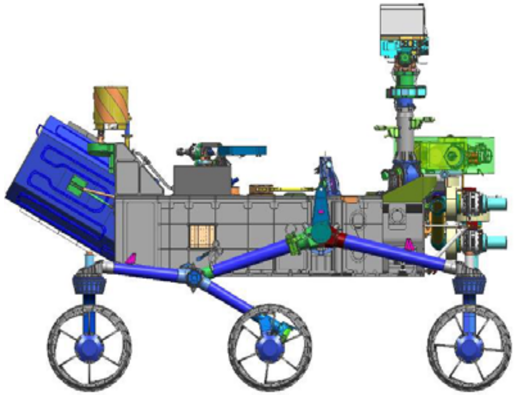
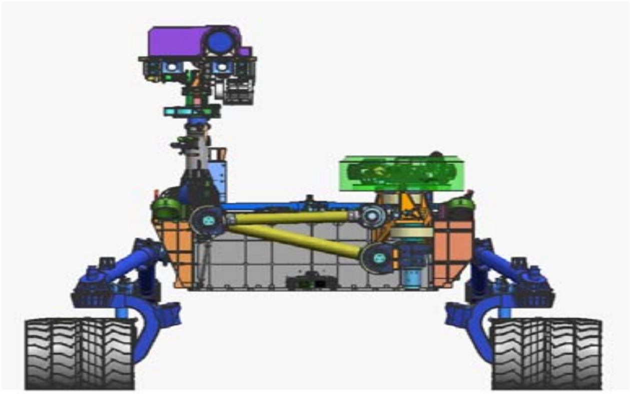


Rover Sizes and complexity have increased



Curiosity/M2020 rover size comparison





Curiosity science payload

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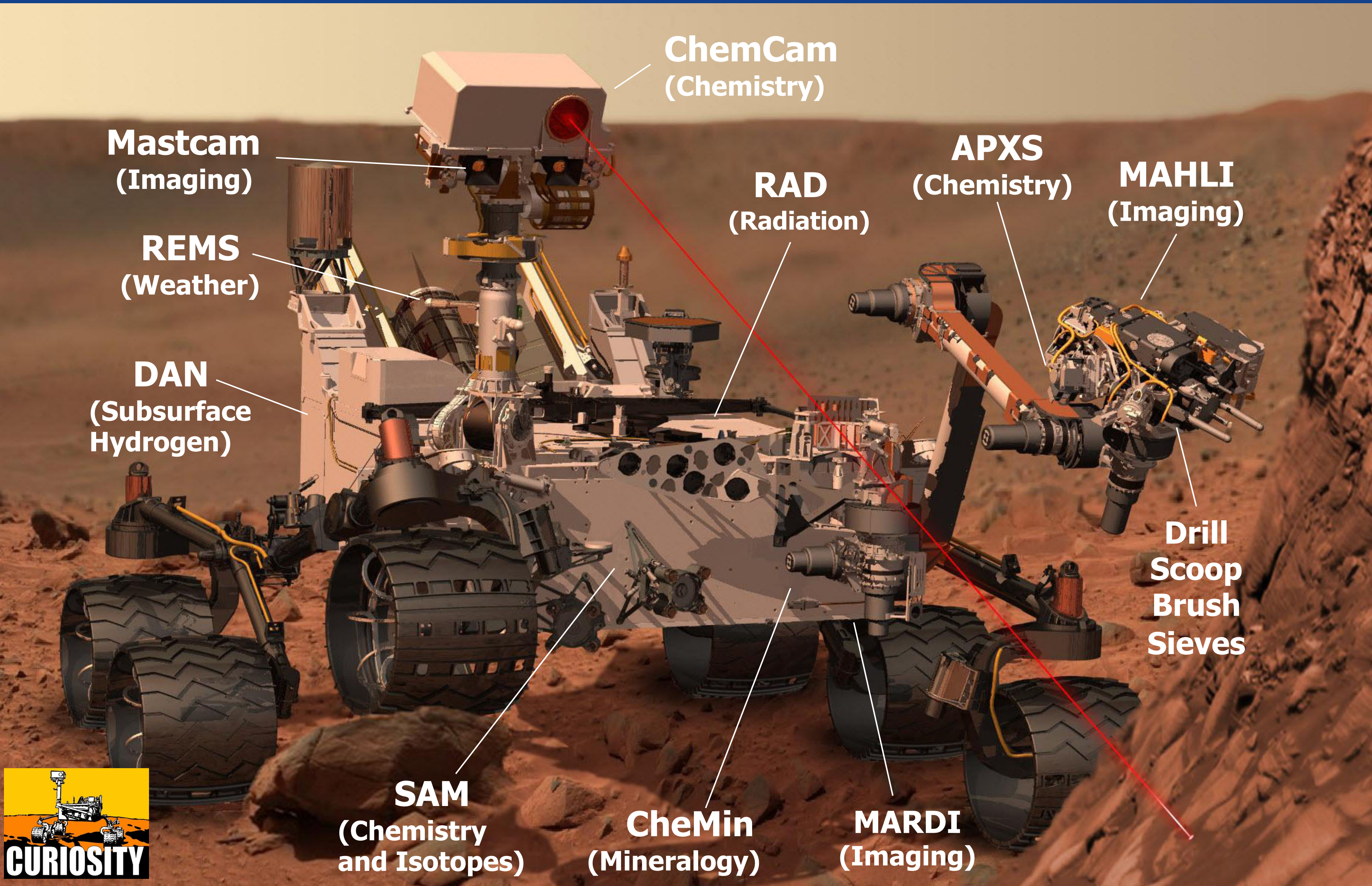

Curiosity/M2020 rover size comparison

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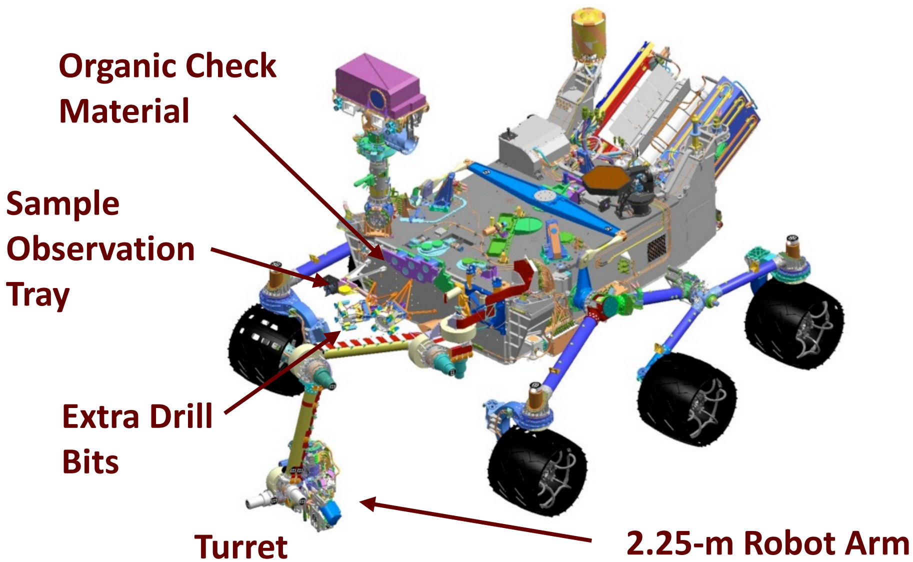
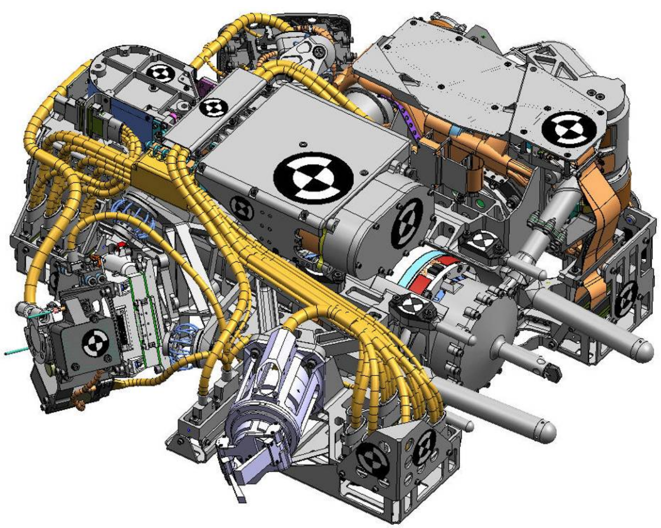


- Cleans rock surfaces with a brush
- Places and holds the APXS and MAHLI instruments
- Acquires samples of rock or soil with a powdering drill or scoop
- Sieves the samples (to 150 µm or 1 mm) and delivers them to instruments or an observation tray
- Exchanges spare drill bits



Landing site: Aeolis Mons – Gale Crater

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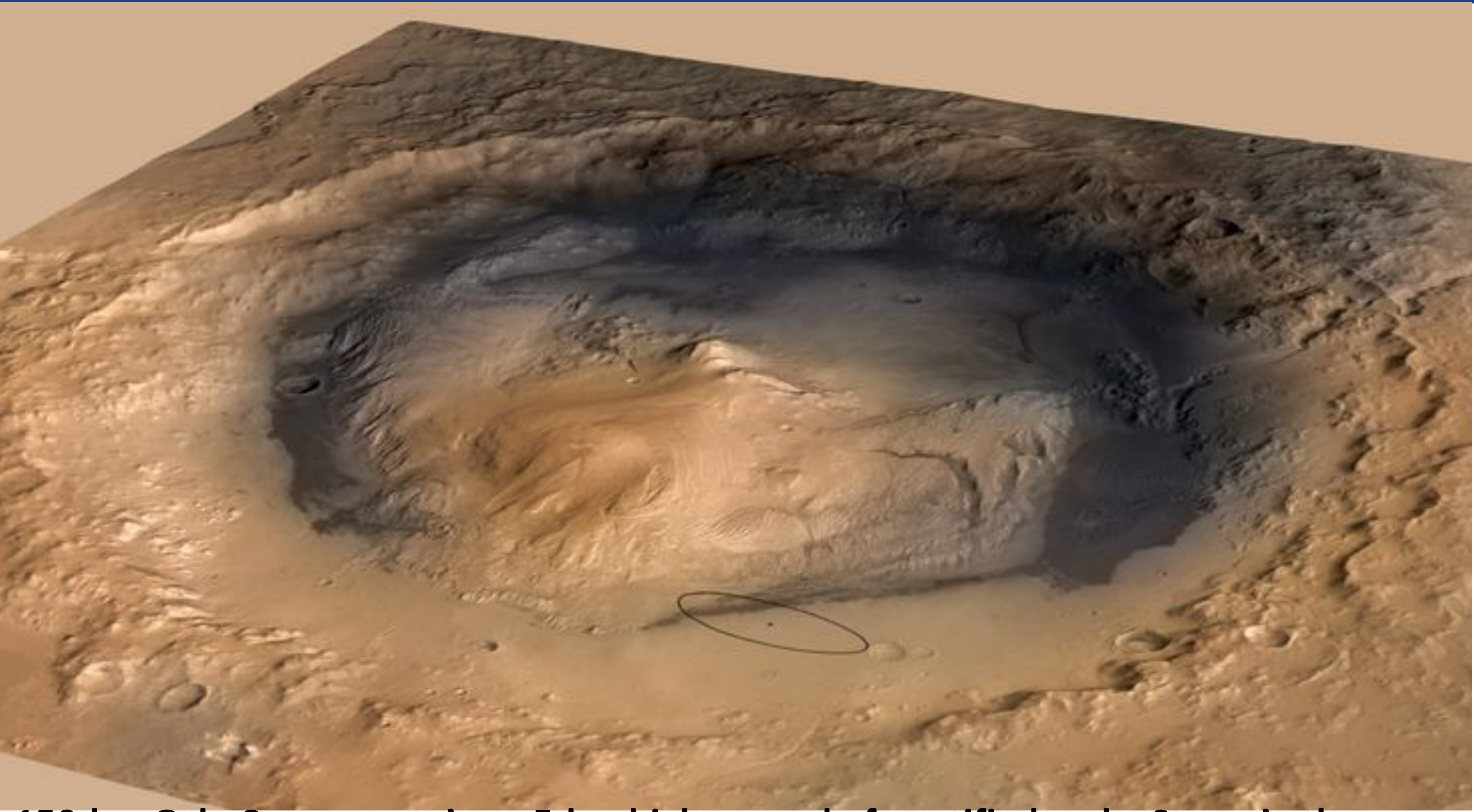

150-km Gale Crater contains a 5-km high mound of stratified rock. Strata in the lower section of the mound vary in mineralogy and texture, suggesting that they may have recorded environmental changes over time.

Mission Overview

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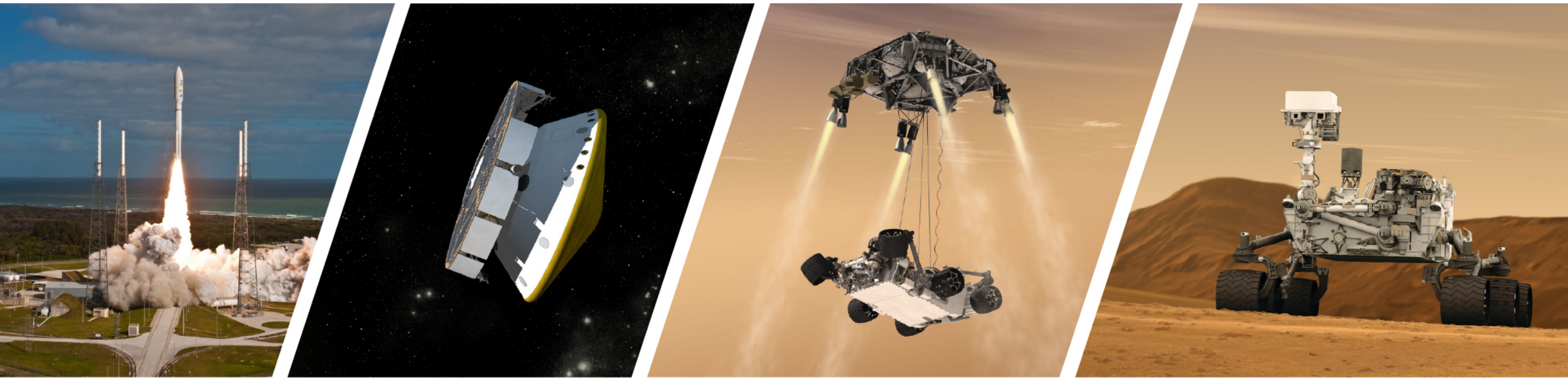


LAUNCH
- MSL Class/Capability LV
- Period: Jul/Aug 2020

CRUISE/APPROACH
- 7.5 month cruise
- Arrive Feb 2021

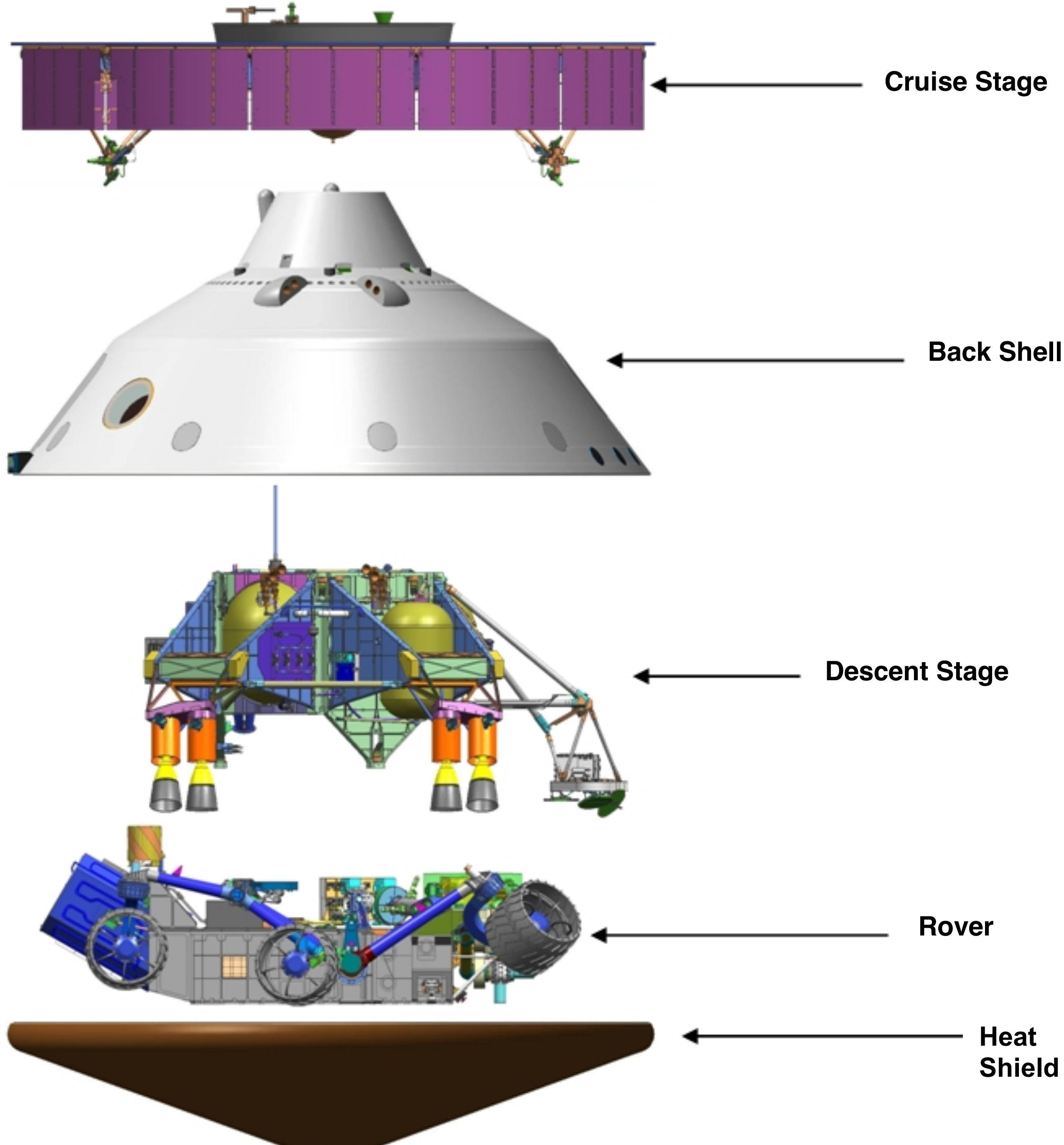
ENTRY, DESCENT & LANDING
- MSL EDL system: guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation

SURFACE MISSION
- Qualified for one & half Mars year
- 20 km traverse distance capability
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

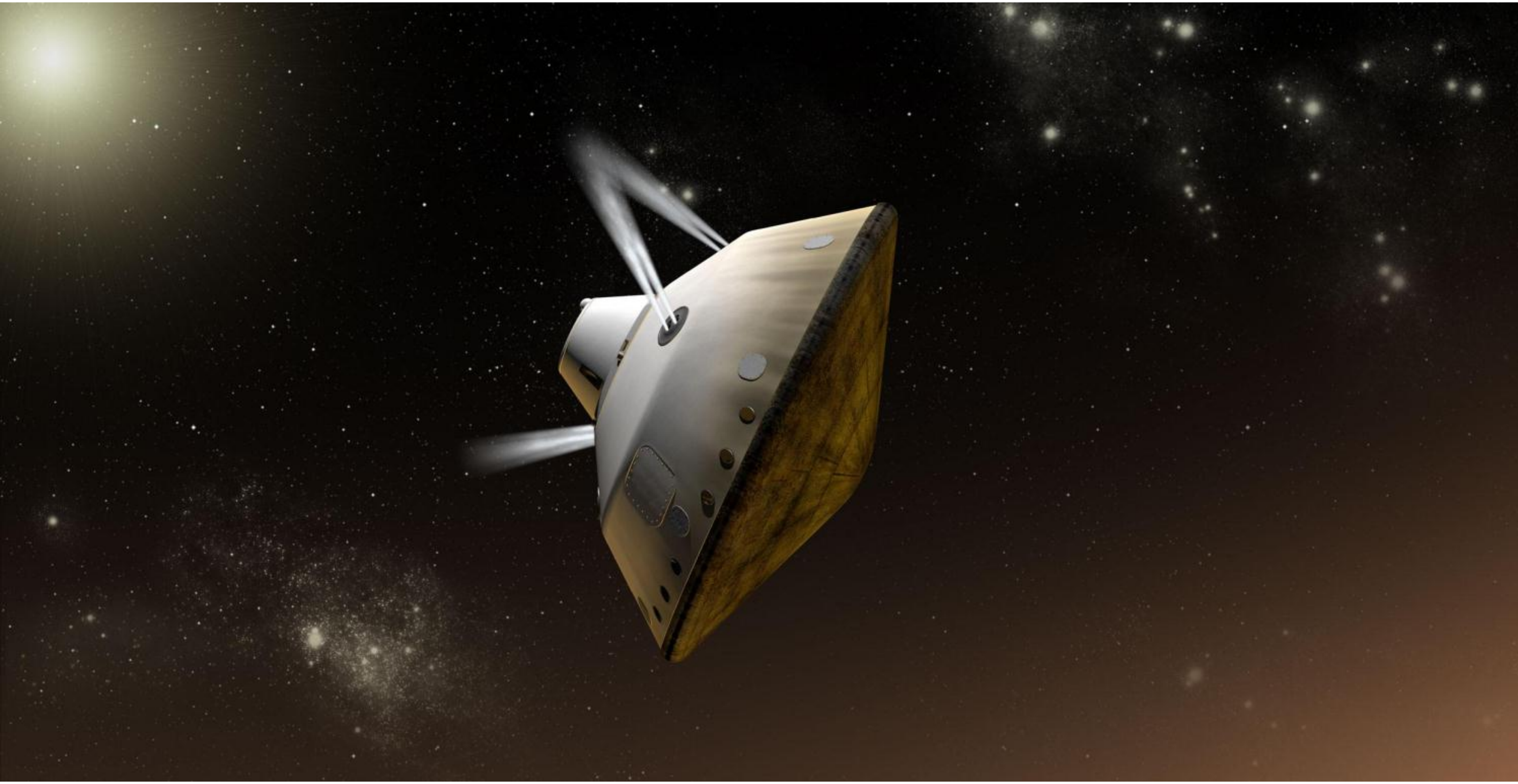
http://mars.jpl.nasa.gov/mars2020/

It is propelled toward Mars by a Centaur upper stage.

Artist's Concept. NASA/JPL-Caltech

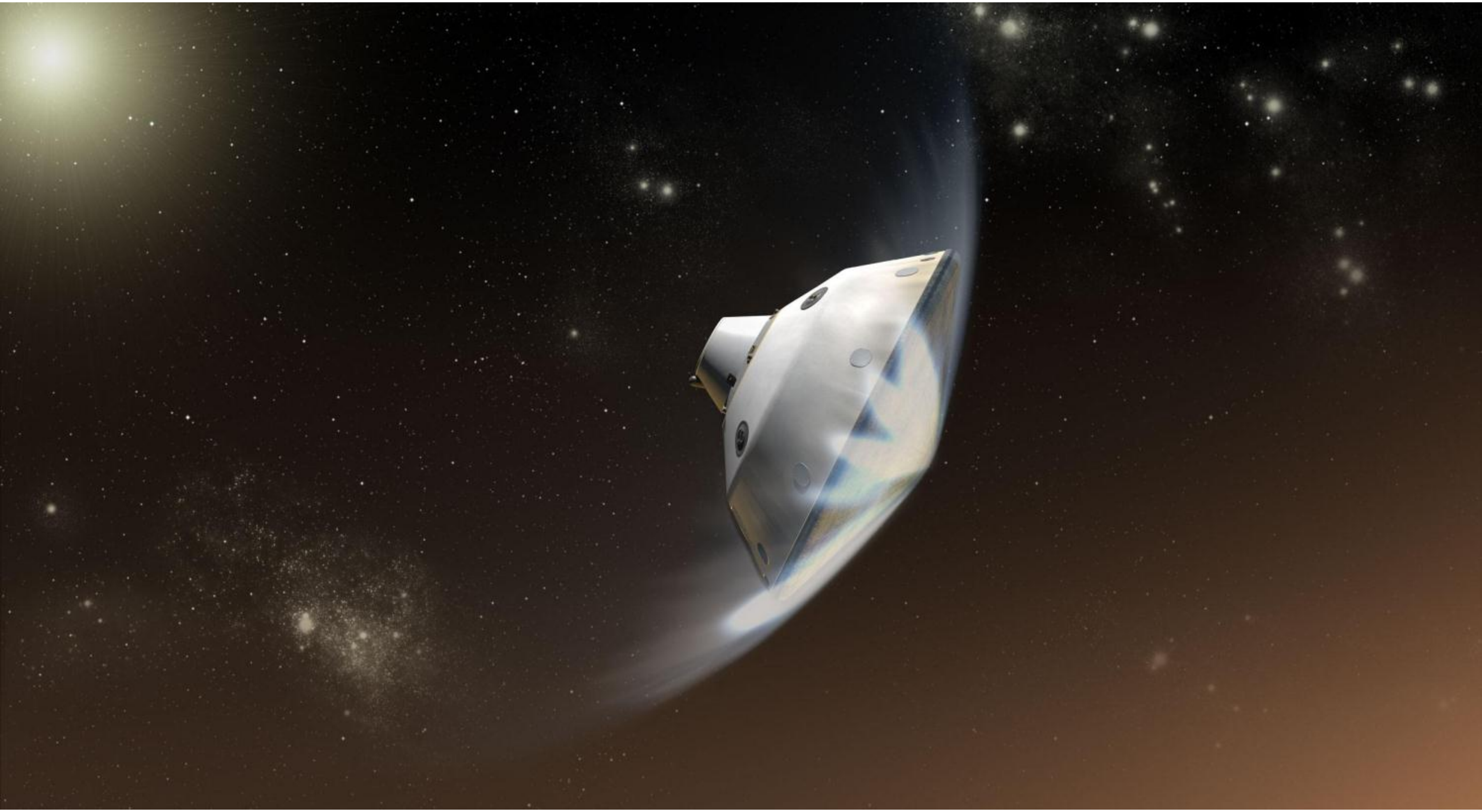


NASAJPL-Caltech



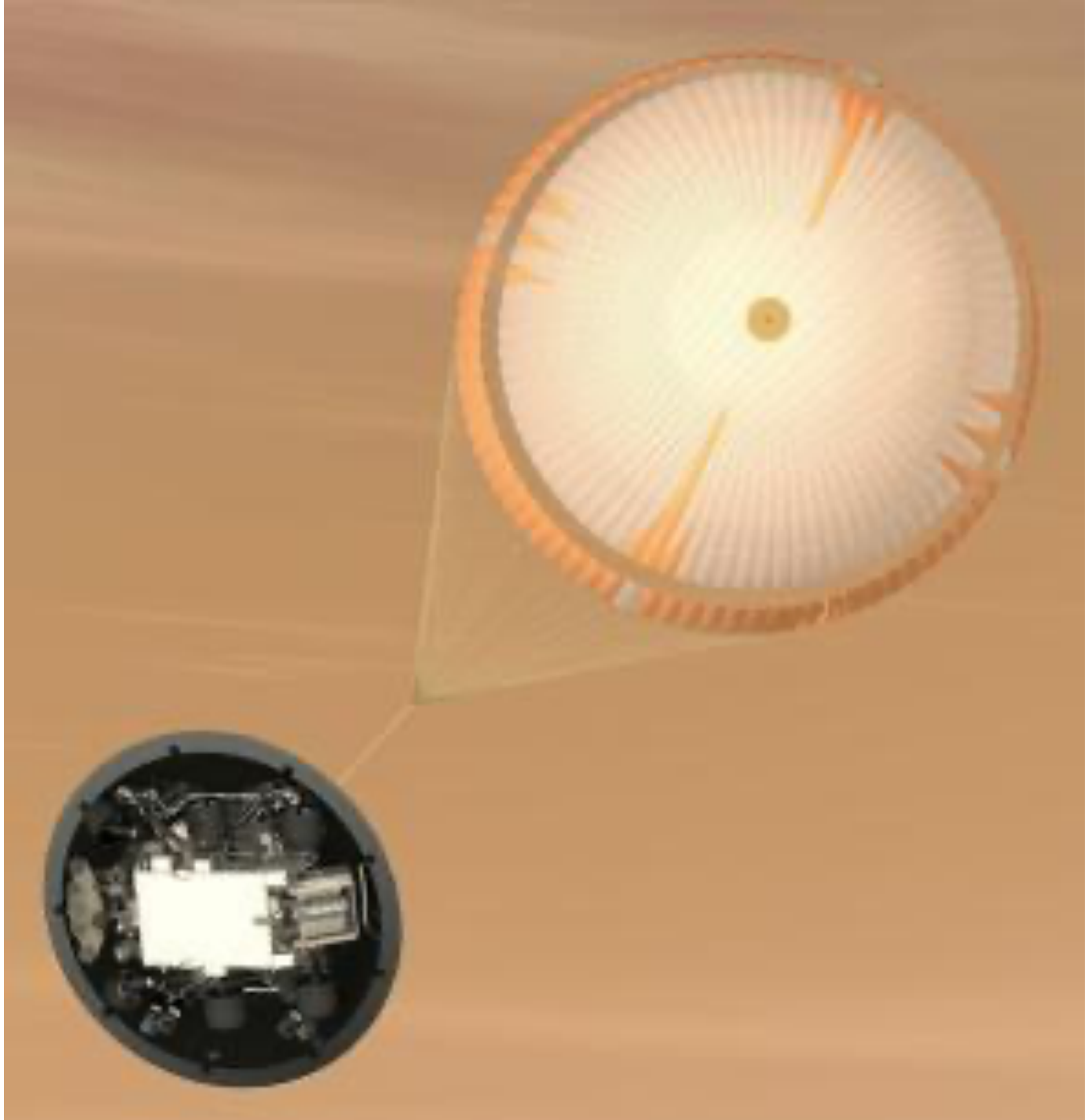
The spacecraft can steer its way through the turbulent atmosphere so it can land more accurately.

Artist's Concept. NASA/JPL-Caltech



The heat shield may reach 3,800 degrees Fahrenheit!

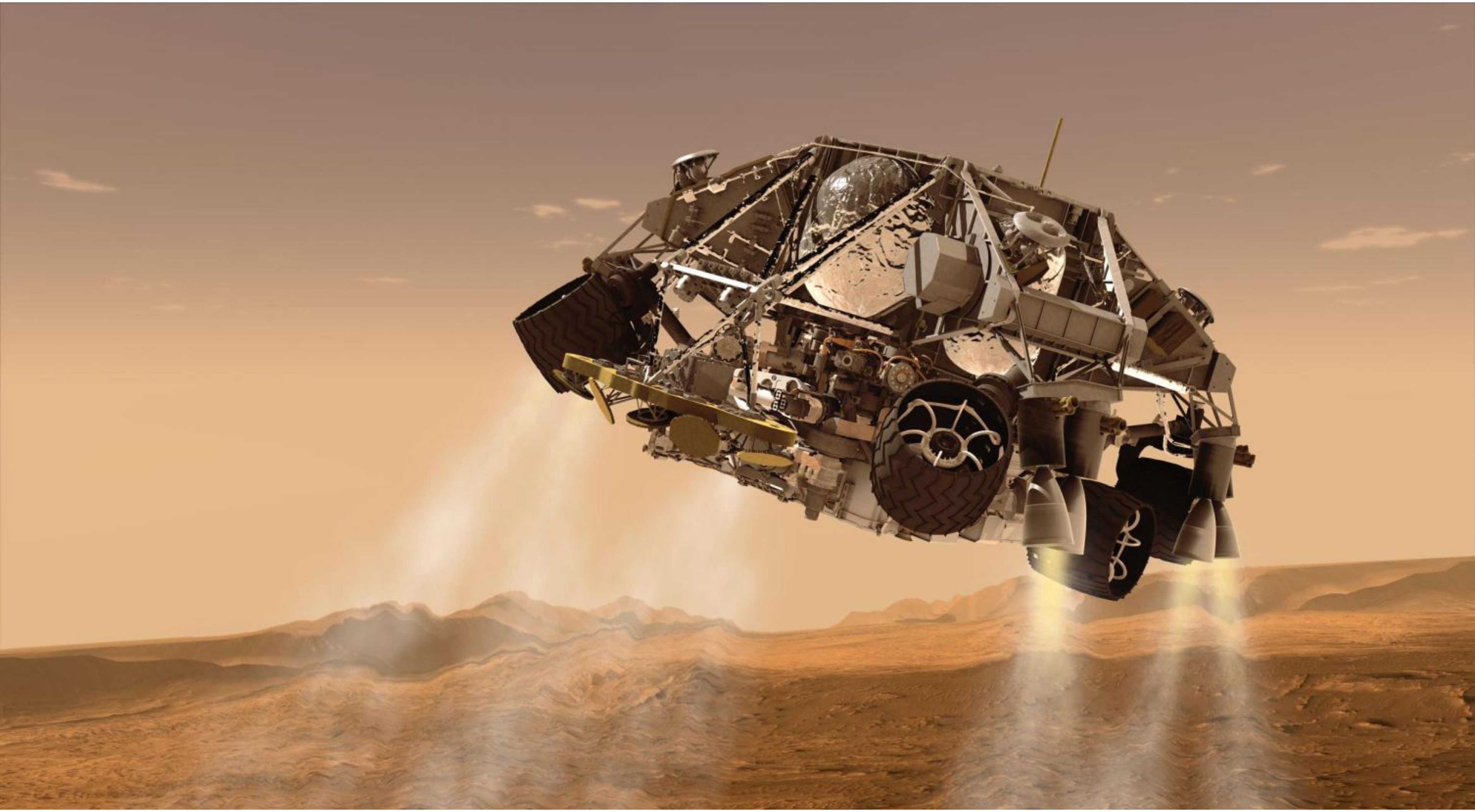
Artist's Concept. NASA/JPL-Caltech



Artist's Concept. NASA/JPL-Caltech

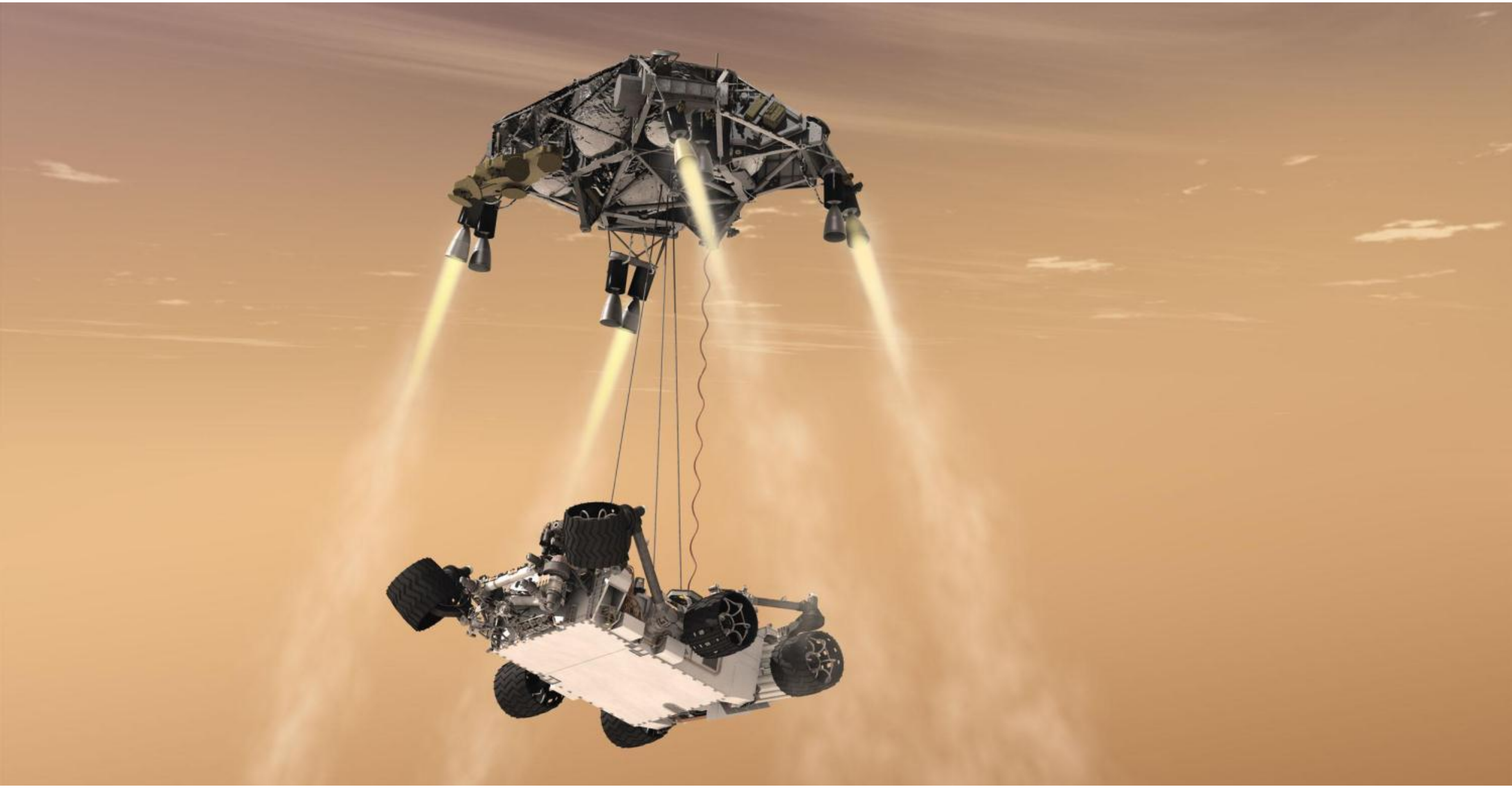
The rover's descent camera begins taking a movie of the remaining five-mile flight to the ground.

Artist's Concept. NASA/JPL-Caltech



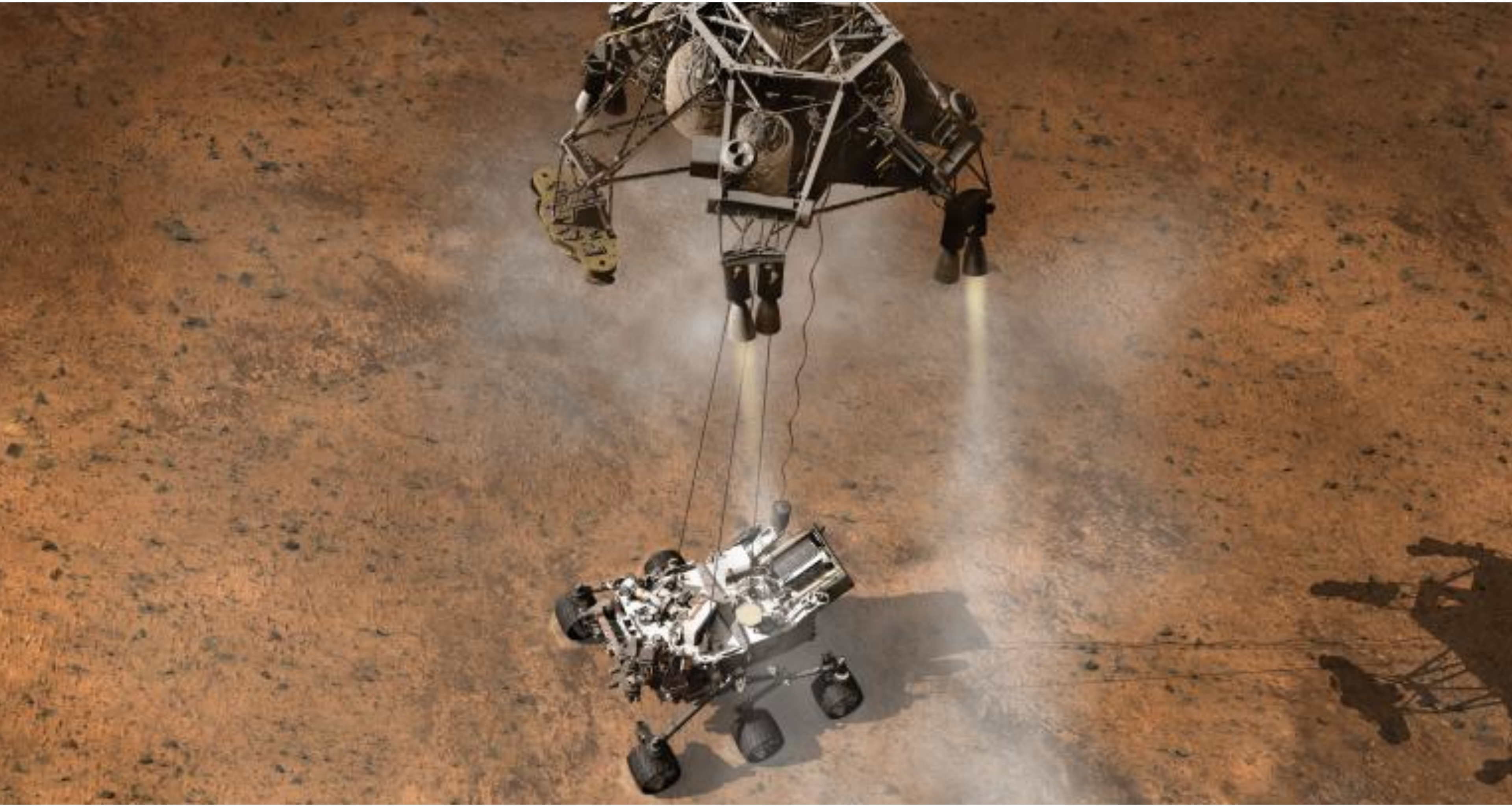
As it descends, the rover uses radar to measure its speed and altitude, which it uses to land safely.

Artist's Concept. NASA/JPL-Caltech



Coiled electronics and communications cables also unspool from the descent stage. This configuration is known as the “Sky Crane.”

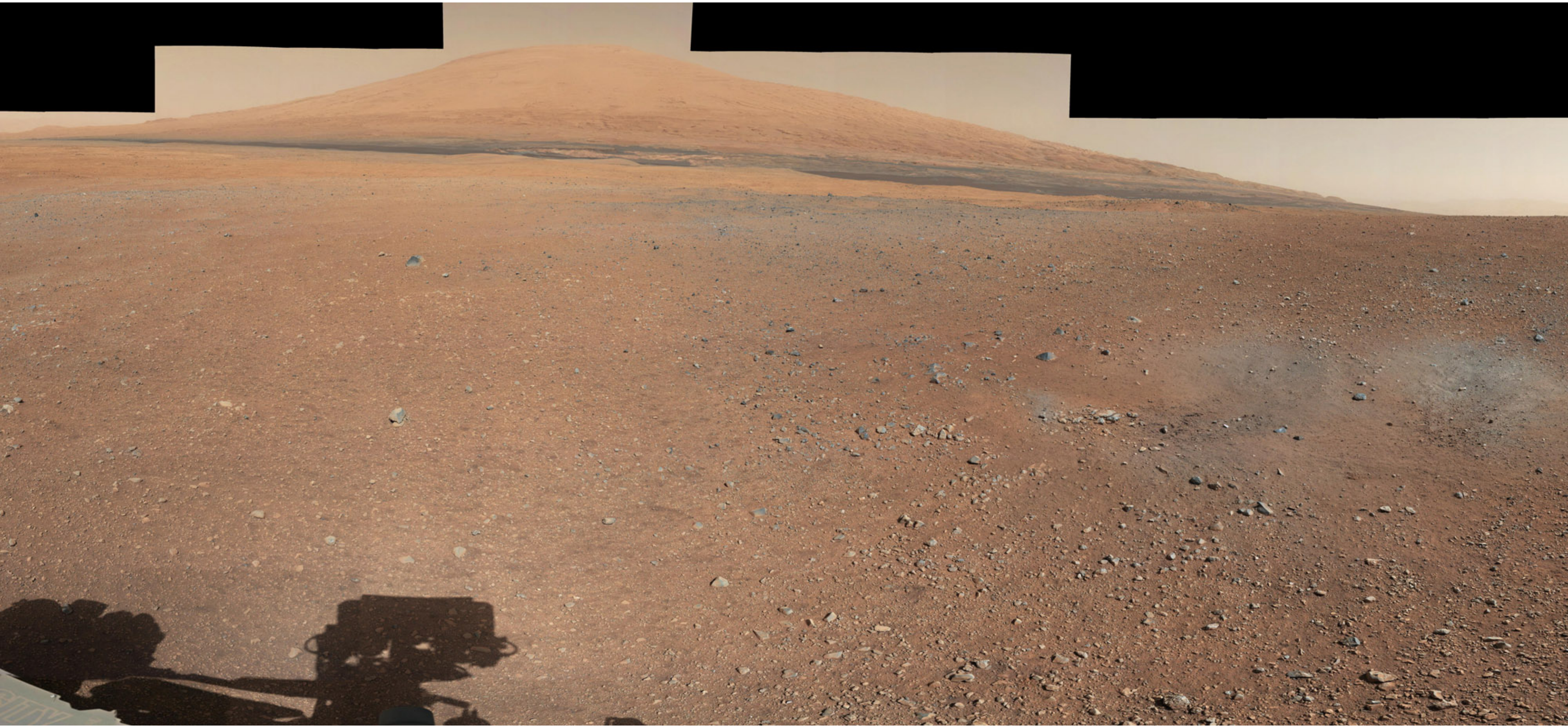
Artist’s Concept. NASA/JPL-Caltech



Less than seven minutes before, it was traveling at 20,000 kilometers per hour!

Artist's Concept. NASA/JPL-Caltech

Landing site: Aeolis Mons



Mastcam mosaic of Mount Sharp, descent rocket scours, and rover shadow

Landing site: Aeolis Mons – Gale Crater

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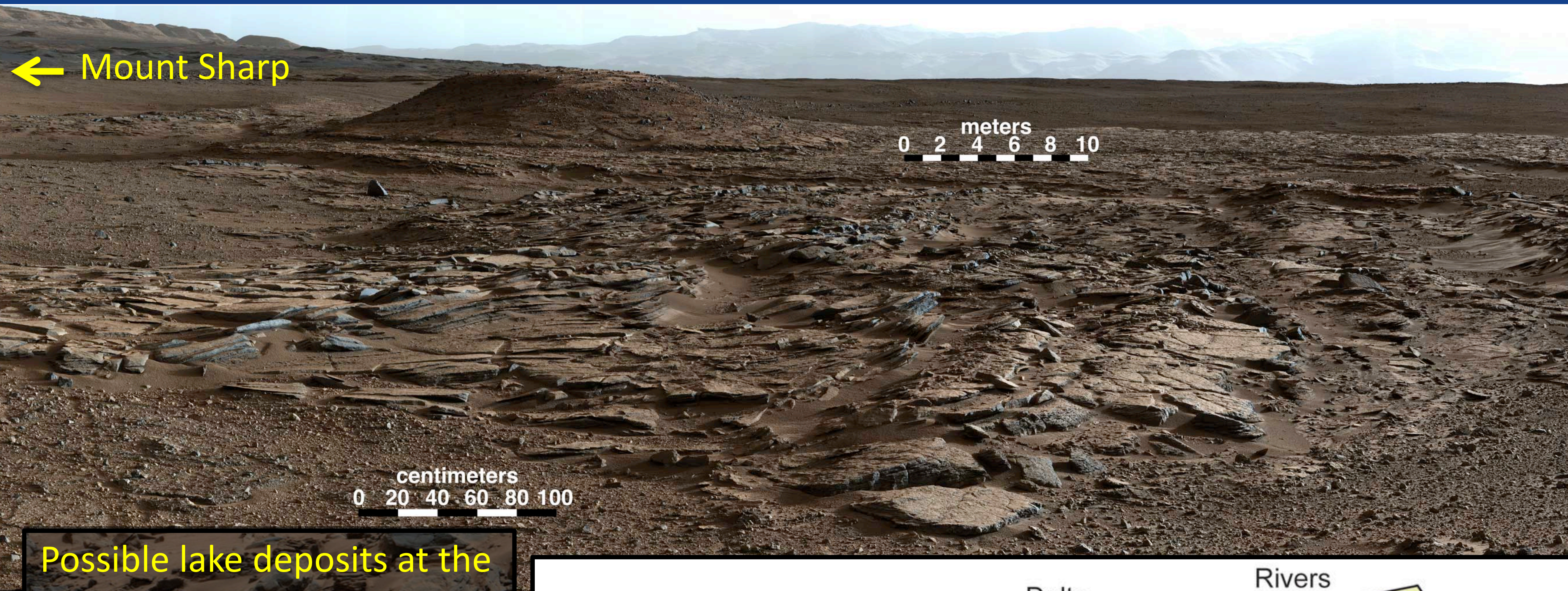
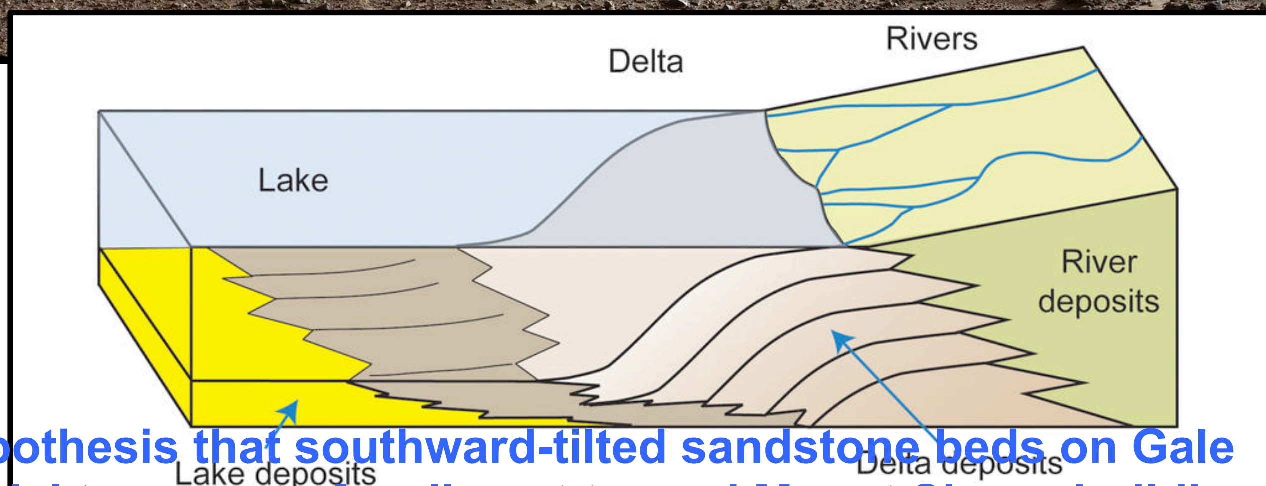



Possible lake deposits at the base of Mount Sharp



Curiosity is exploring a hypothesis that southward-tilted sandstone beds on Gale Crater's plains indicate fluvial transport of sediment toward Mount Sharp, building up lake deposits there.

Landing site: Aeolis Mons – Gale Crater

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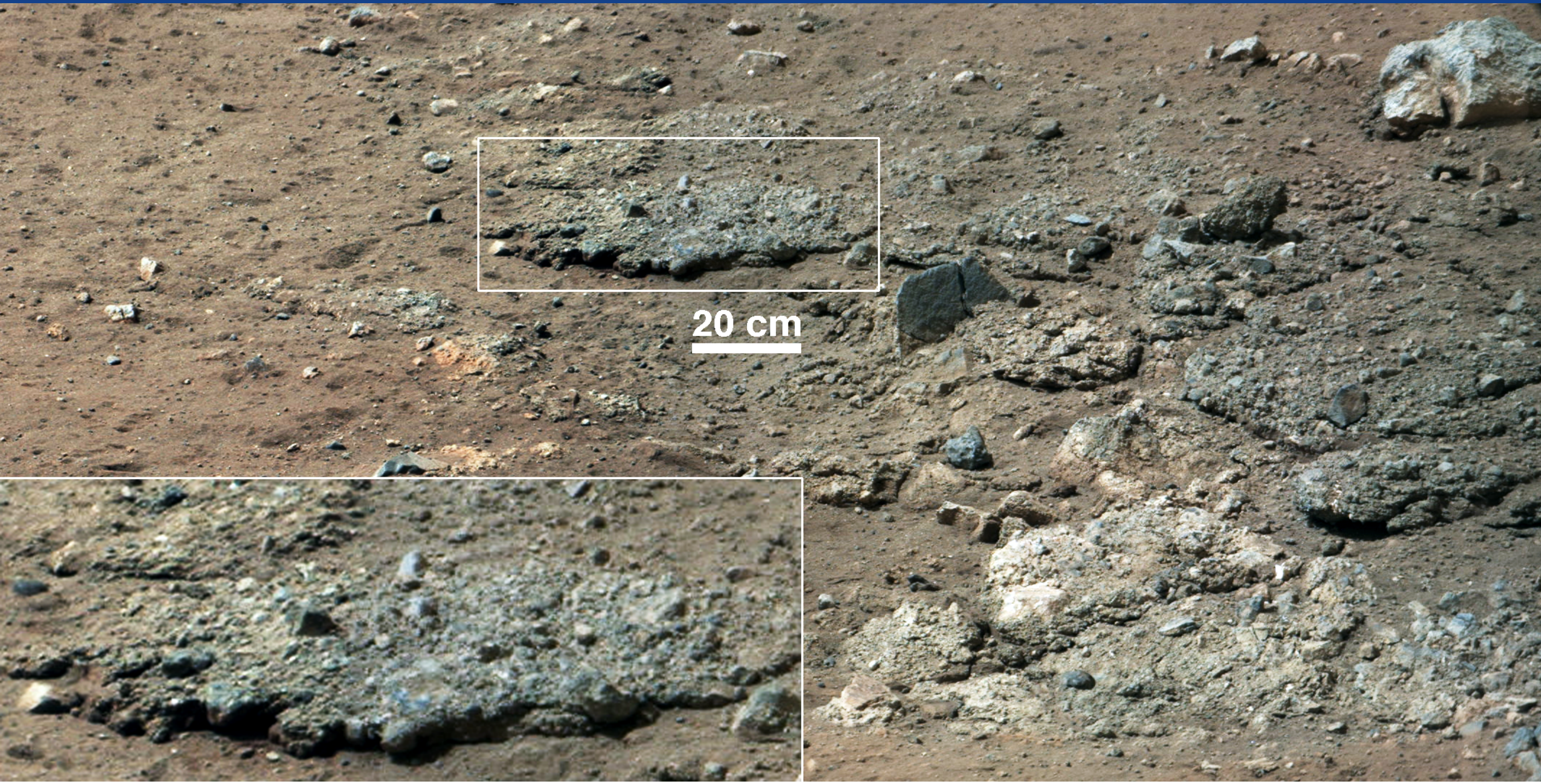

The ground scoured by Curiosity's descent rockets first revealed bedrock

Landing site: Aeolis Mons – Gale Crater

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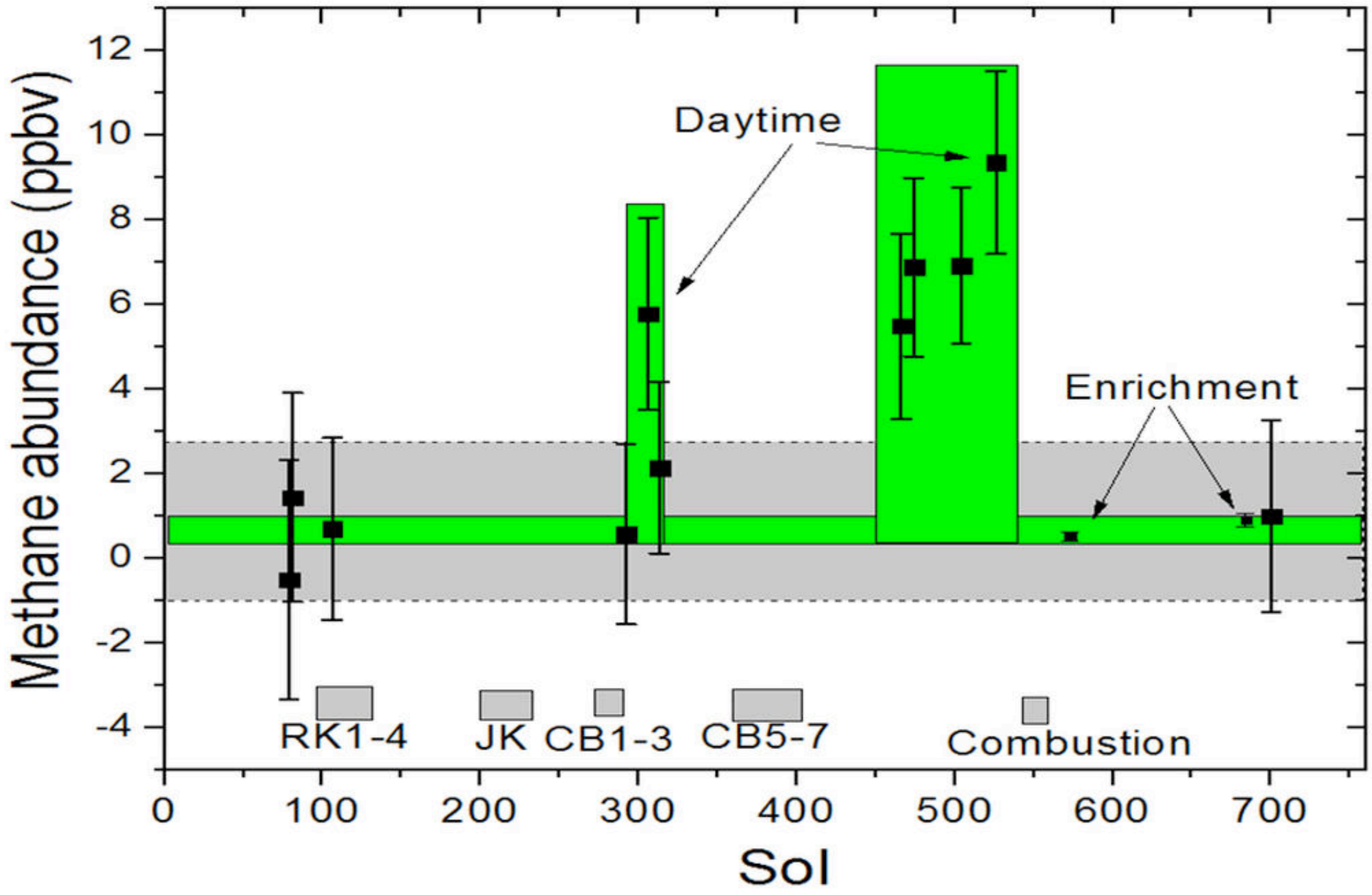
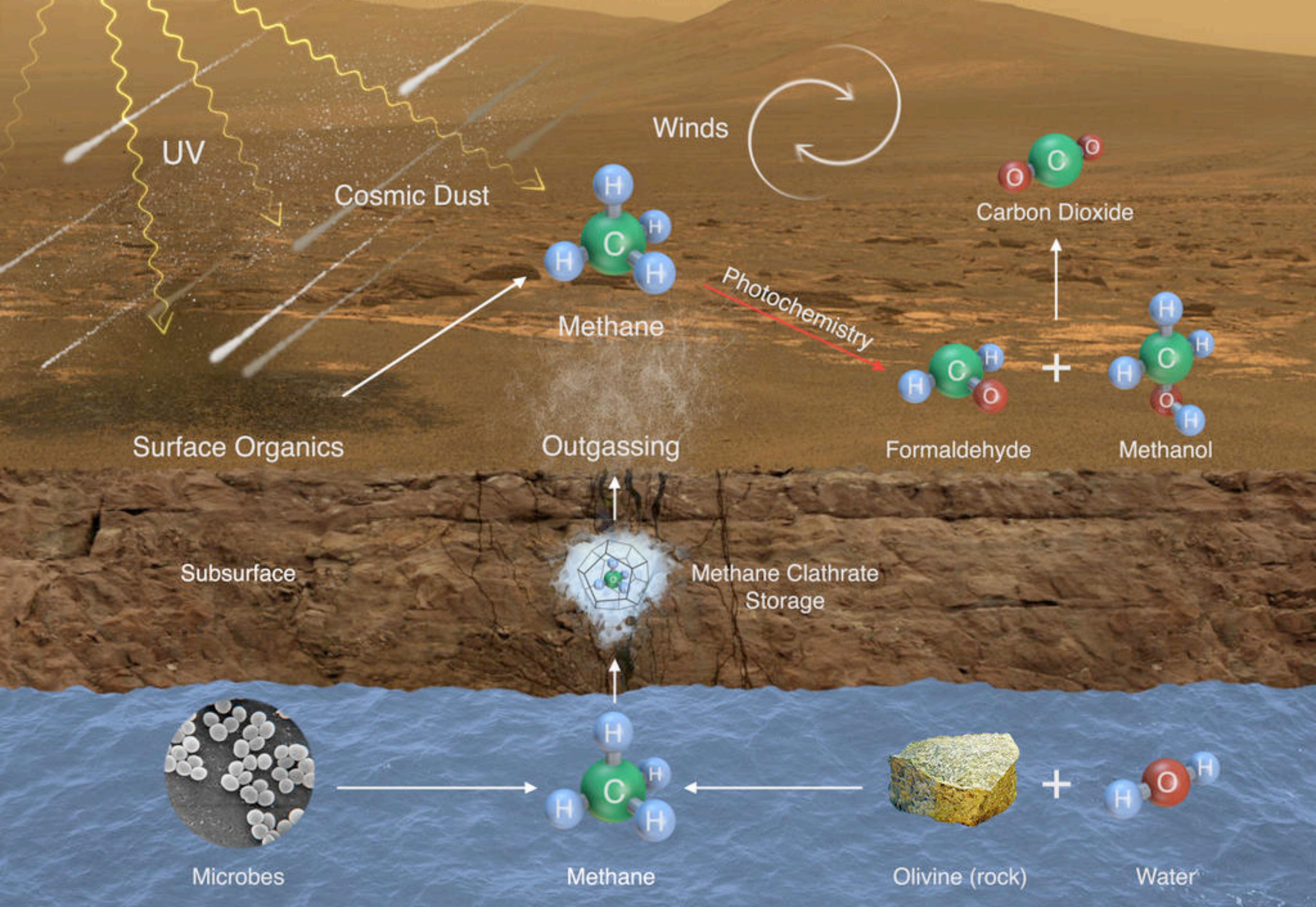


Curiosity measured a background methane abundance of 0.7 ppbv and a ten-fold enhancement that lasted ~ 60 sols

Possible Methane Sources and Sinks



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An Ancient Habitable Environment at Yellowknife Bay

- The regional geology and fine-grained rock suggest that the John Klein site was at the end of an ancient river system or within an intermittently wet lake bed
- The mineralogy indicates sustained interaction with liquid water that was not too acidic or alkaline, and low salinity. Furthermore, conditions were not strongly oxidizing.
- Key chemical ingredients for life are present, such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur
- The presence of minerals in various states of oxidation would provide a source of energy for primitive organisms

Notes on Organics

- **This is the first-ever detection of a martian organic chemical.**
- **It took many analyses of rocks and soils, as well as additional analyses of blanks and calibration standards on Mars and on Earth, in order to verify this discovery.**
- **SAM detected simple hydrocarbon molecules in which some of the hydrogen was replaced with chlorine. This could have happened on Mars, or within the instrument, through reaction with perchlorate compounds that are known to be widespread on Mars.**
- **Simple organic molecules do not require biology for their formation. However, they are building blocks of life. More importantly, we now can study what environments preserve organics on Mars' surface, increasing our ability to search for other life-related materials.**

ENV observations on Gale Crater

Several Instruments are providing a picture of the near surface environment:

- REMS: pressure, Temperature, downwelling UV radiation, Relative Humidity, Surface temperature, winds.
- ChemCam: atmospheric composition.
- MastCam: atmospheric opacities.
- DAN: subsurface Hydrogen
- RAD: high energy ionizing radiation.
- NavCams: atmospheric opacities, cloud and dustdevil tracking.

Second longest surface pressure record

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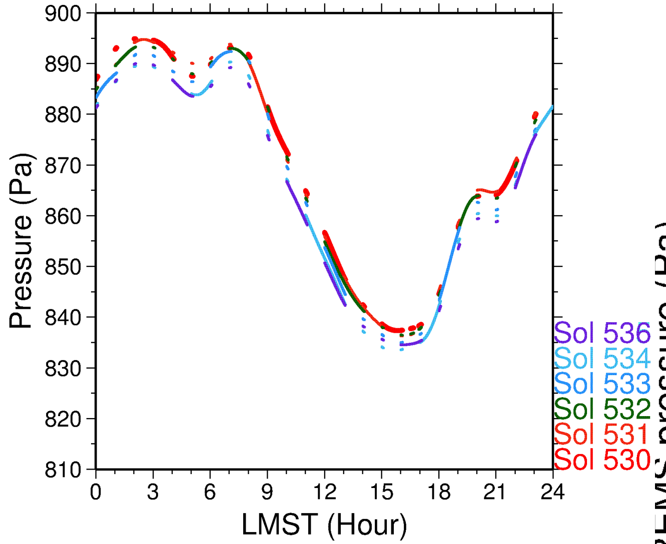
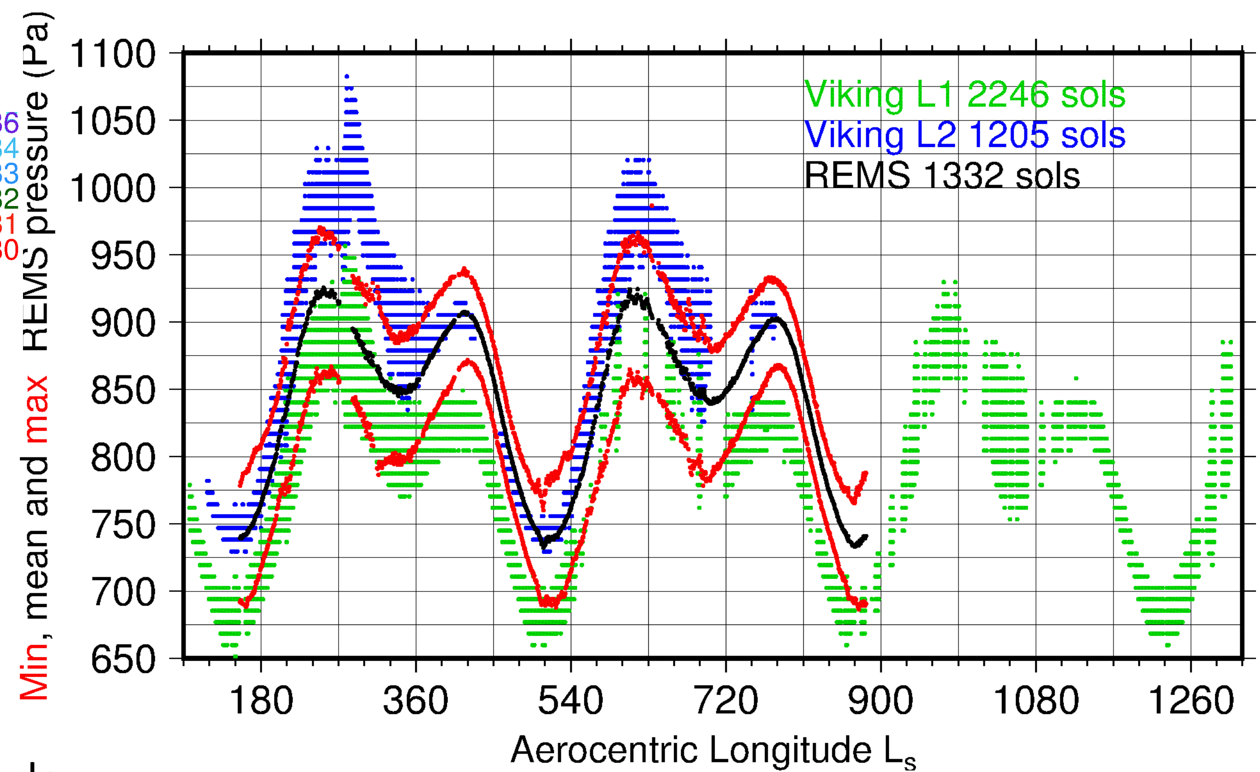


2 Martian years of surface pressure registered by Curiosity.



- Wider diurnal pressure cycle
- Smaller difference between Spring and Autumn maxima due to near Equatorial location.
- CO_2 cycle is reflected in pressure annual cycle.
- Wave signatures also abundant during seasons with higher atmospheric dust.

Longest surface temperature record

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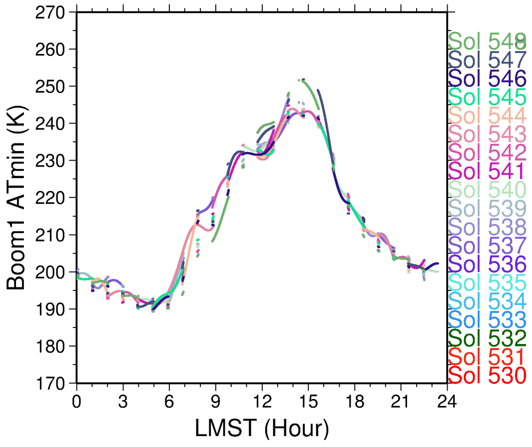

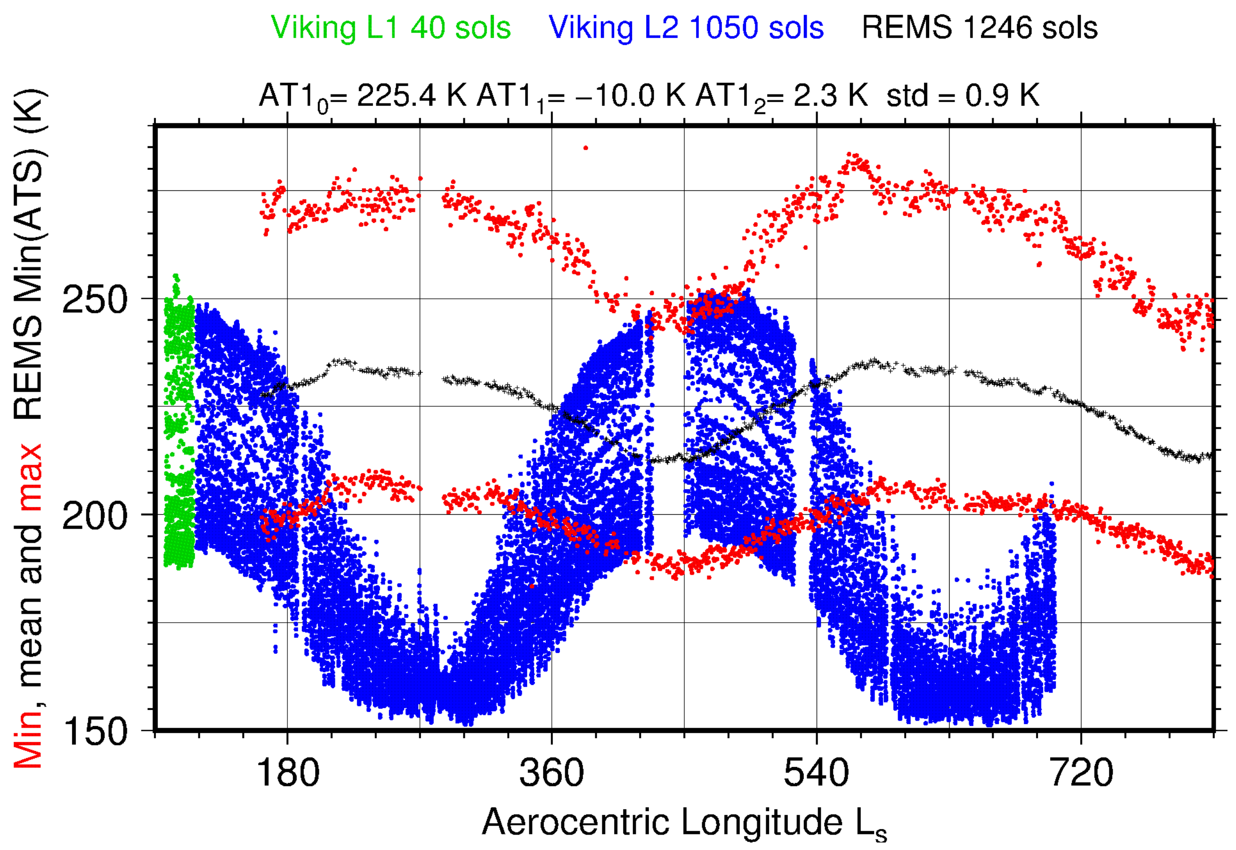

- Warmer temperatures than at the Viking locations.
- Smaller difference between Winter and Summer due to near Equatorial location.
- Gale's winter overlaps with Viking L2 Summer because of Mars's axis inclination putting the Sun at same angular distance from Viking L2 and Curiosity locations.

Surface skin temperature

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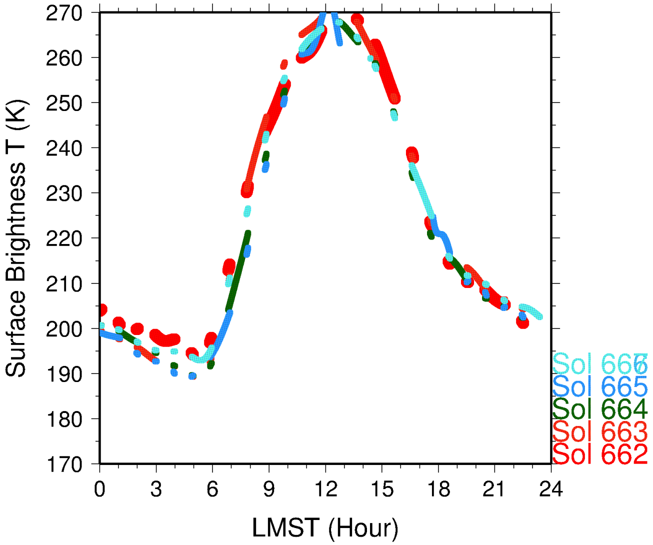

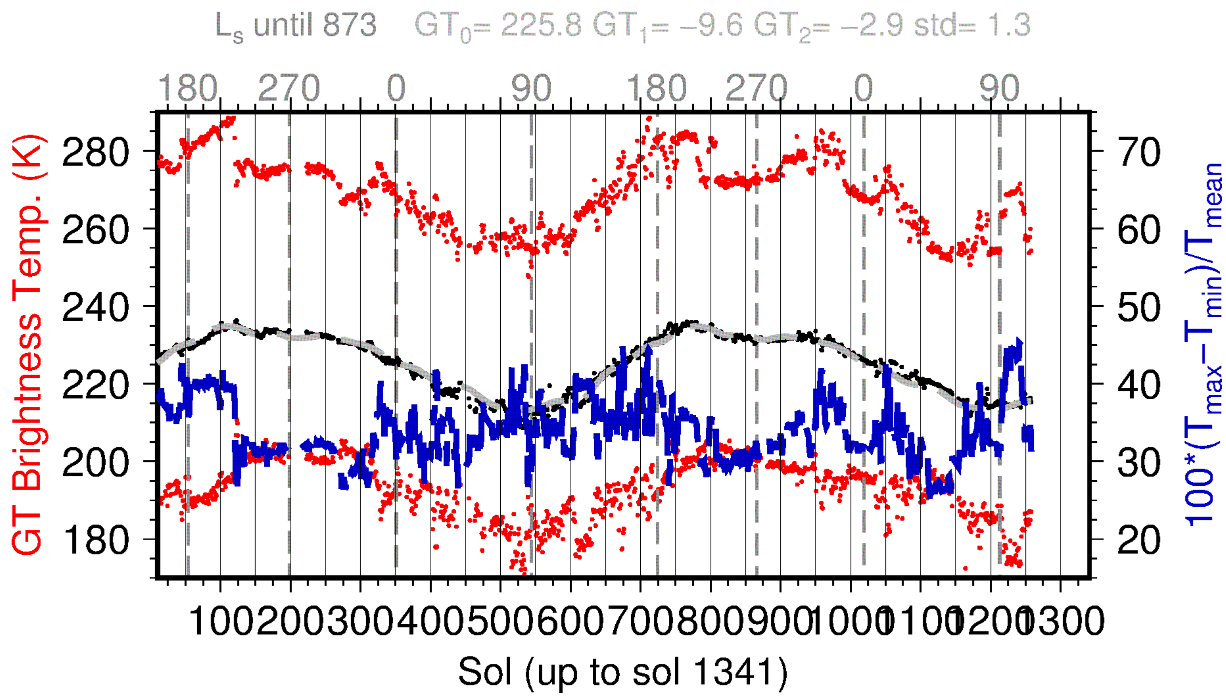

Night time Relative Humidity and mixing ratio

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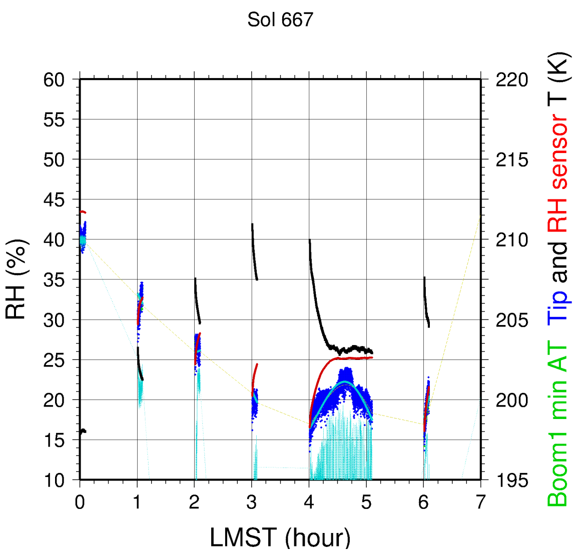

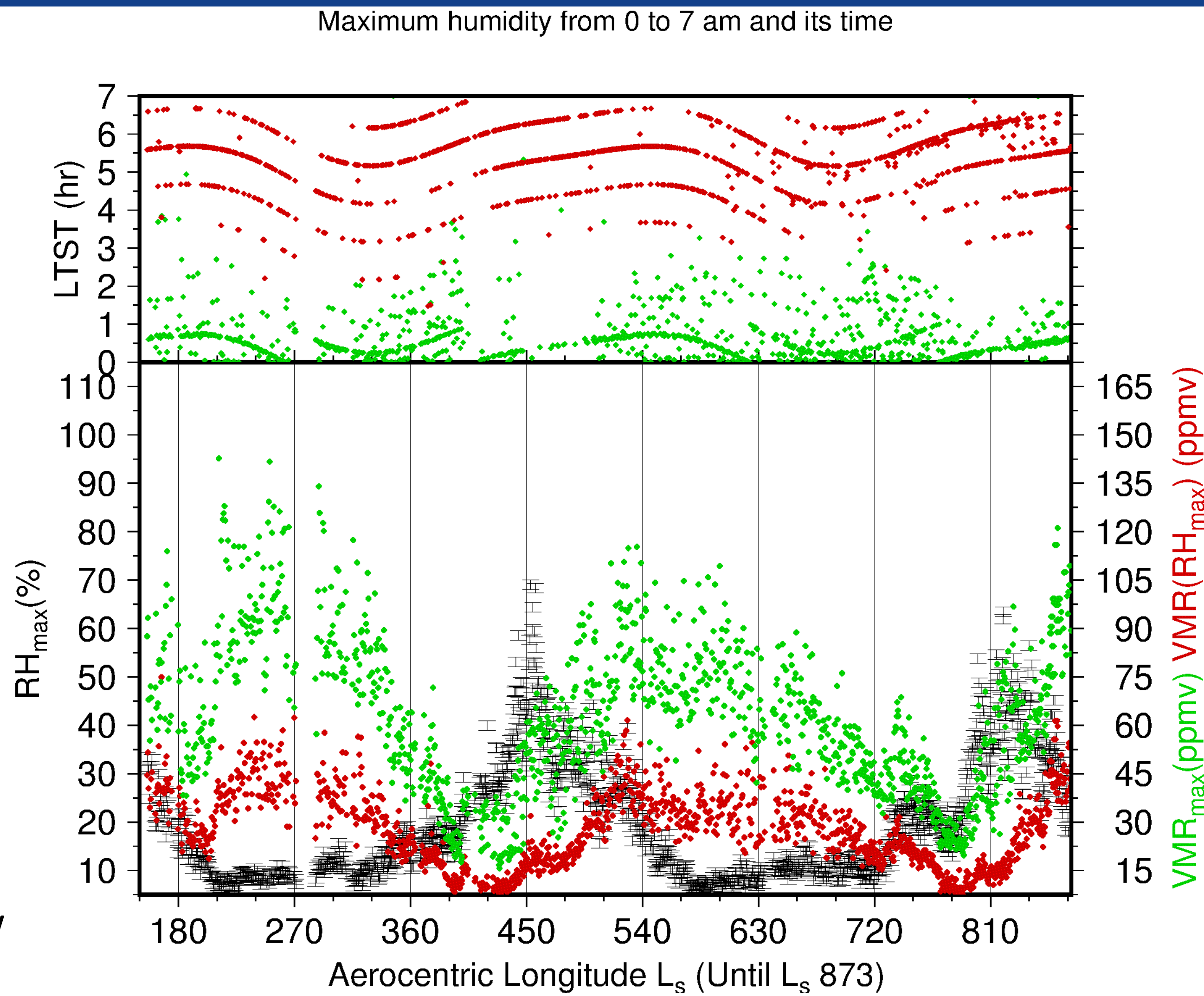

RH night time cycle typically follows the temperature cycle.

100% RH has not been reached on Gale

Night time mixing ratios show a different cycle with higher water vapor in the warm season.

Wind tracking

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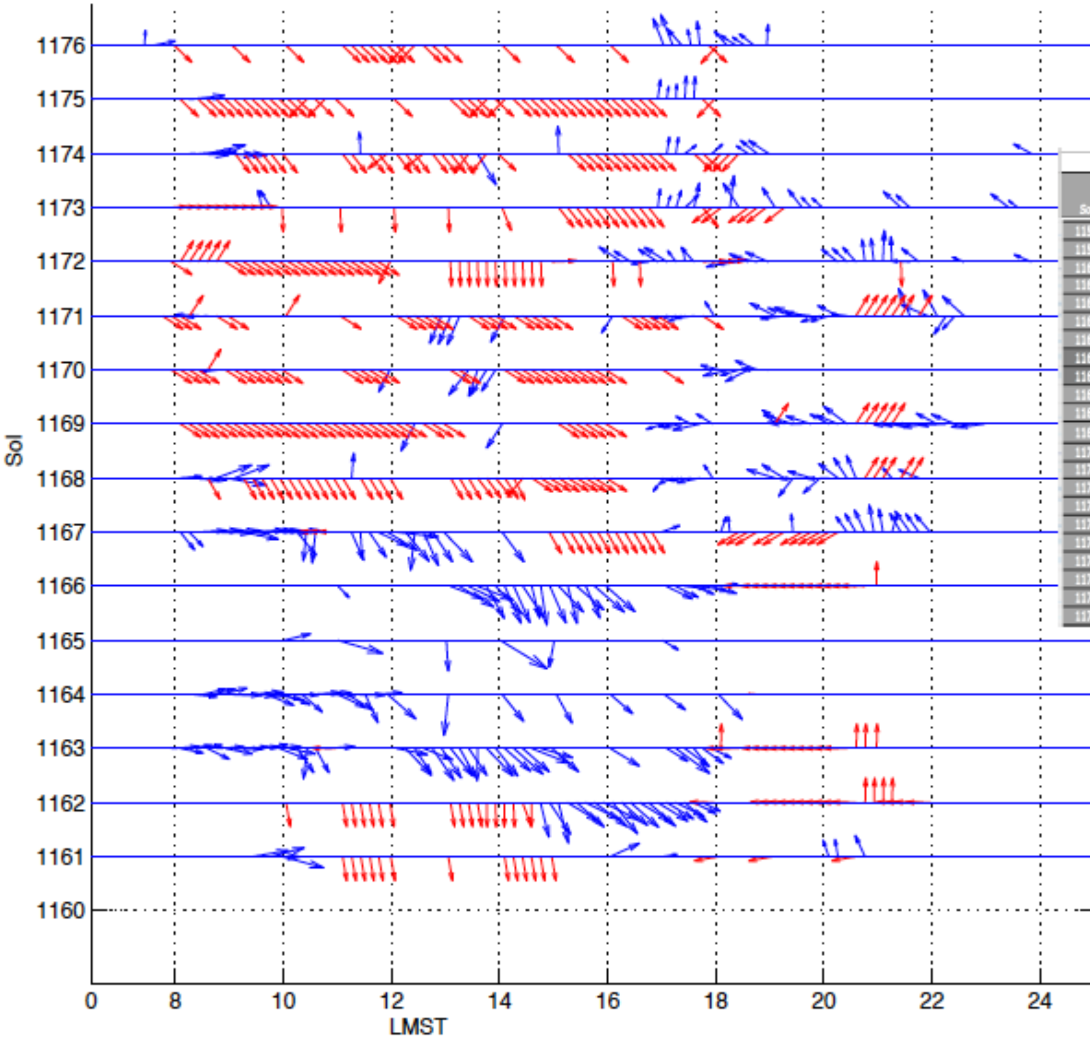
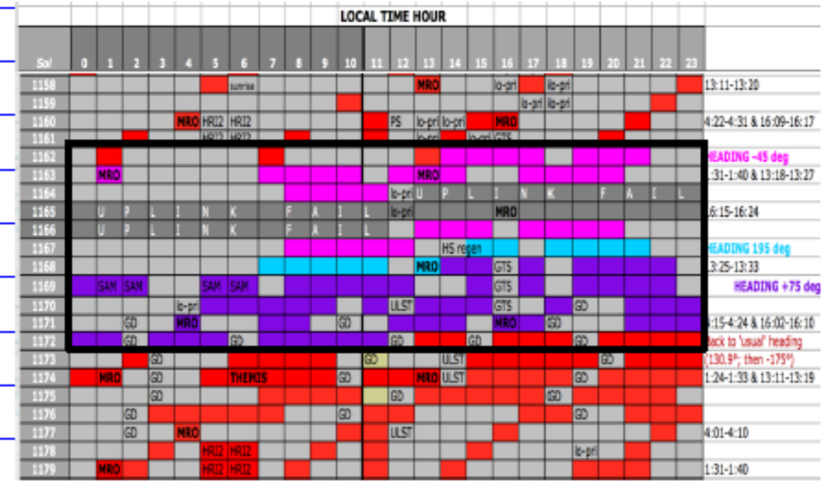
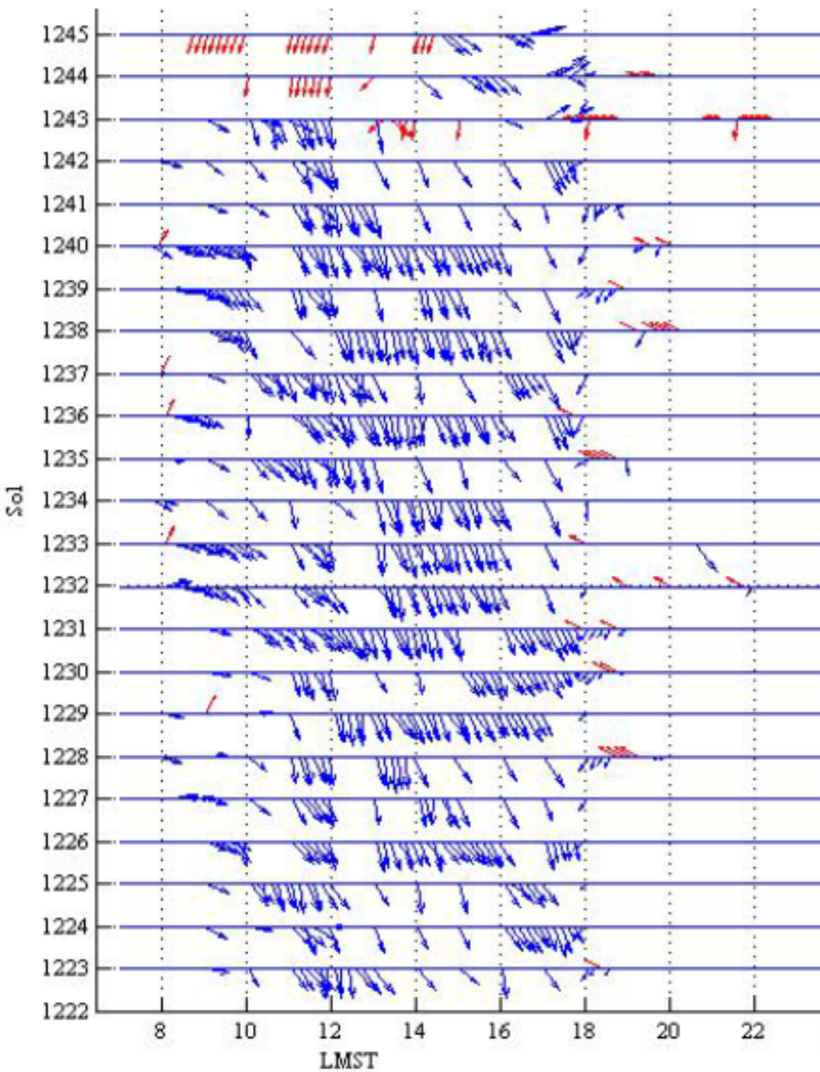


Wind sensor was damaged during landing and winds are a compromised measurement.



Sometimes most of the winds come from the direction where REMS cannot track them.

Wind tracking



Sol	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1223						sunrise																	lo	lo
1224							sunrise										MRO						lo	
1225	lo-pri			MRO	MRO																			lo
1226	lo-pri					HRI2	HRI2							change detection						lo-pri	lo-pri			
1227						HRI2	HRI2													lo-pri		lo-pri		
1228		MRO													HS							lo-pri		
1229						sunrise								change detection			MRO	lo-pri						
1230							sunrise										lo-pri		lo-pri					
1231																		lo-pri	lo-pri					
1232						HRI2	HRI2							MRO	lo-pri									
1233		MRO				HRI2	HRI2							lo-pri		lo-pri								
1234															lo-pri	lo-pri								
1235						sunrise					lo-pri	lo-pri												
1236					HRI2 0330-0630								change detection											
1237												lo-pri	lo-pri											
1238																								
1239																								
1240									lo-pri	lo-pri														
1241				MRO	MRO	sunrise																		
1242					lo-pri		sunrise								HS		GTS							
1243		MRO				sunrise	sunrise							MRO				wind	wind			wind		
1244		lo-pri	lo-pri			HRI2	HRI2										GTS	wind		wind	wind		wind	
1245		lo-pri		lo-pri		HRI2	HRI2										MRO							

When the rover is oriented onto the winds REMS can capture most of the wind cycle.

REMS UV obs *(M Smith)*

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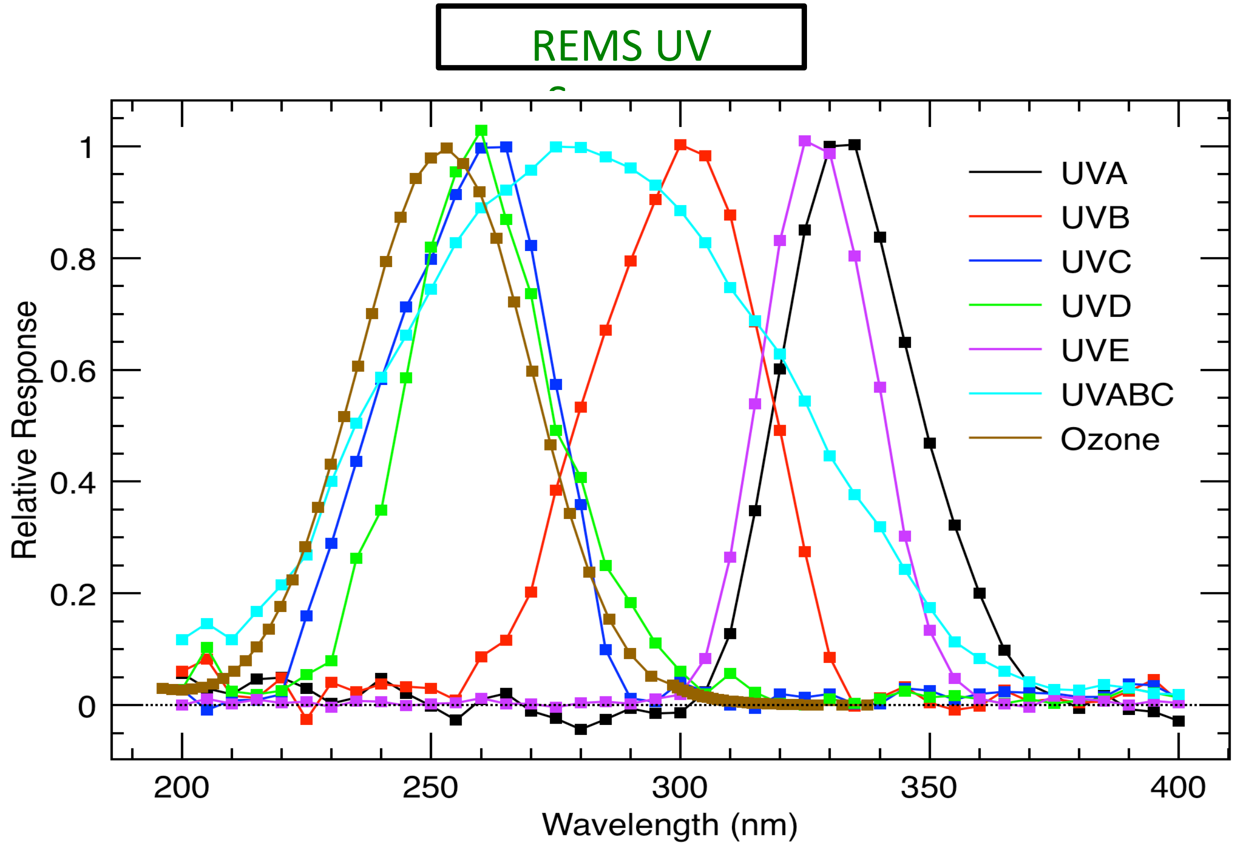

- Six filters in UV from ~250-350 nm
- Mounted on rover deck, nominally view cone centered on nadir with 30° half-width
- Data returned all the time whenever REMS is collecting data

REMS UV obs *(M Smith)*

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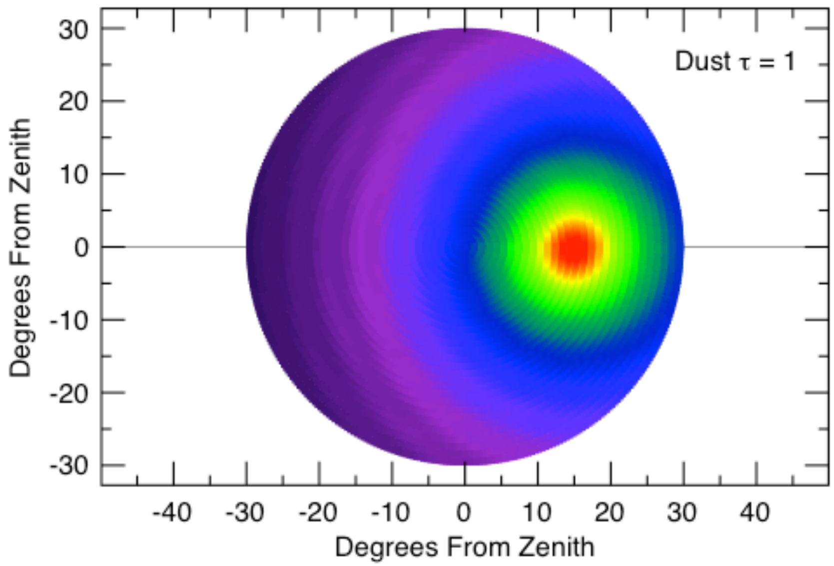
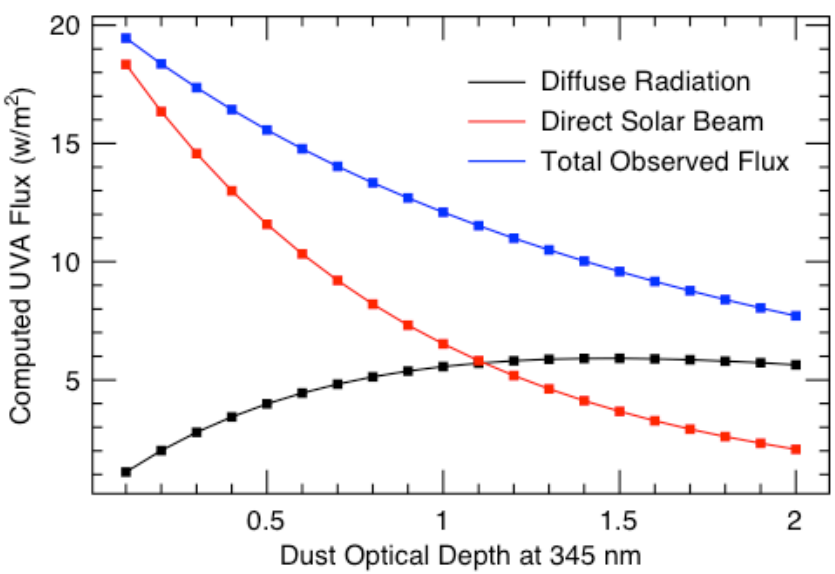
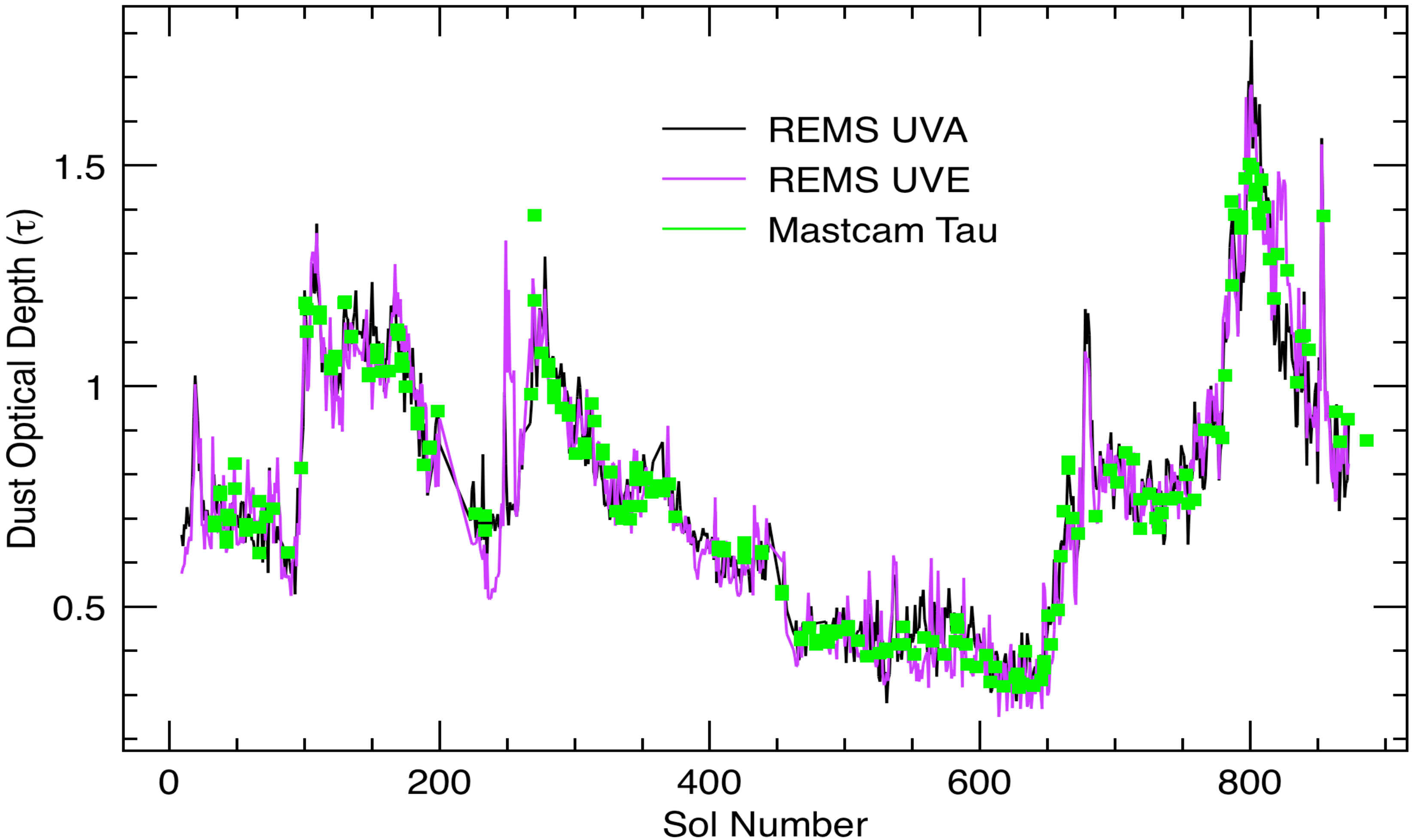




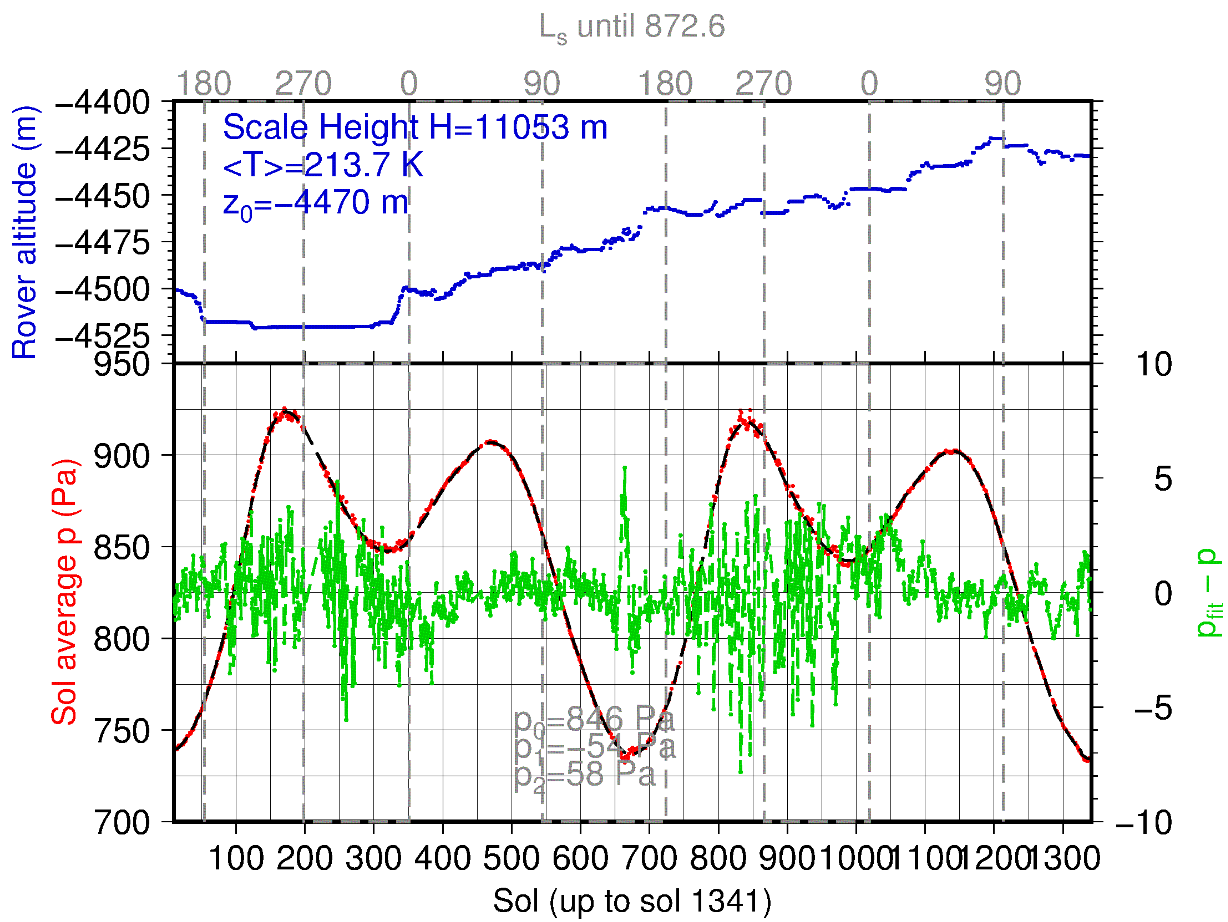
- Observed radiance is direct radiation from solar beam plus diffuse radiation scattered from sky (“sky brightness”)
- Both direct solar beam and diffuse radiation are sensitive to aerosol optical depth (and to other things to a lesser extent)
- REMS UV data can be used to retrieve aerosol optical depth “tau”

REMS UV obs *(M Smith)*

Mastcam tau is better, but REMS UV provides results every sol.



Environmental processes: pressure

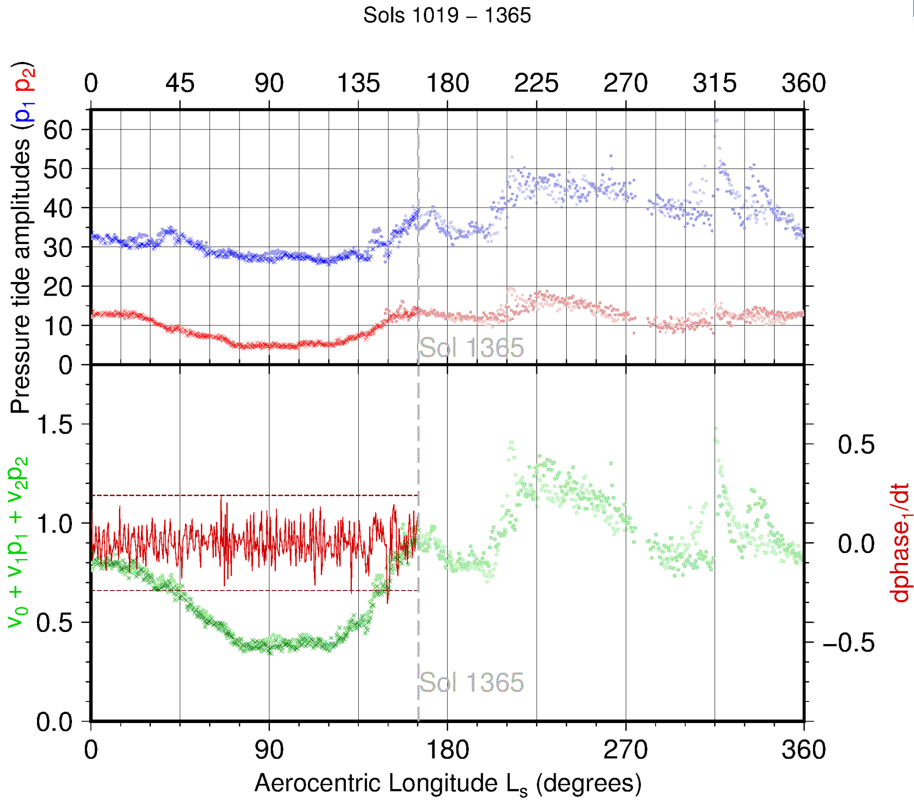


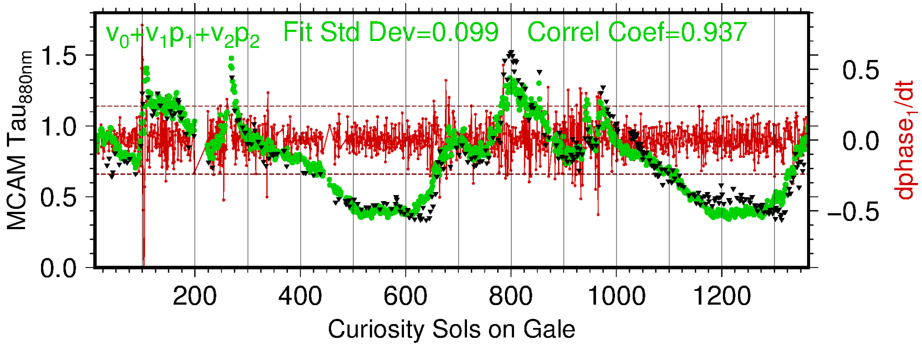
Mean pressure values increase their variability to the dust season as detected by Mcam.

Average temperature of an atmospheric layer centered at z=-4470m is 213.5K if the atmosphere were isothermal.

~ 12K colder than at the rover altitude.

Environmental processes: pressure





Dust cycle impacts the pressure tidal amplitudes and phases *(Ryan & Henry; Zurek 1978; Haberle et al., 2014; Guzewich et al., 2016)*.

Changes in dust also affect the phase of the diurnal pressure tide.

Hydrological processes: search for frost

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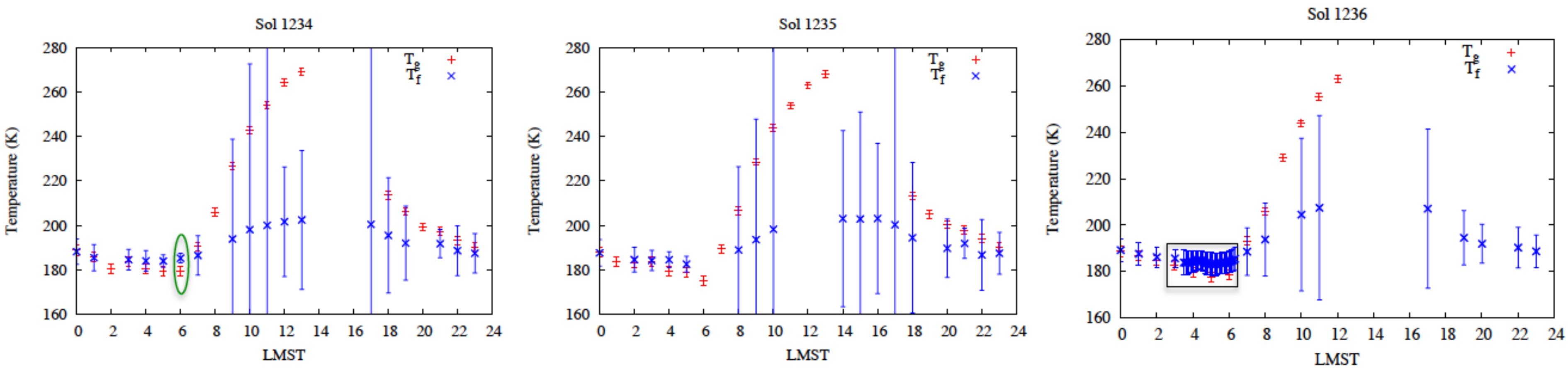
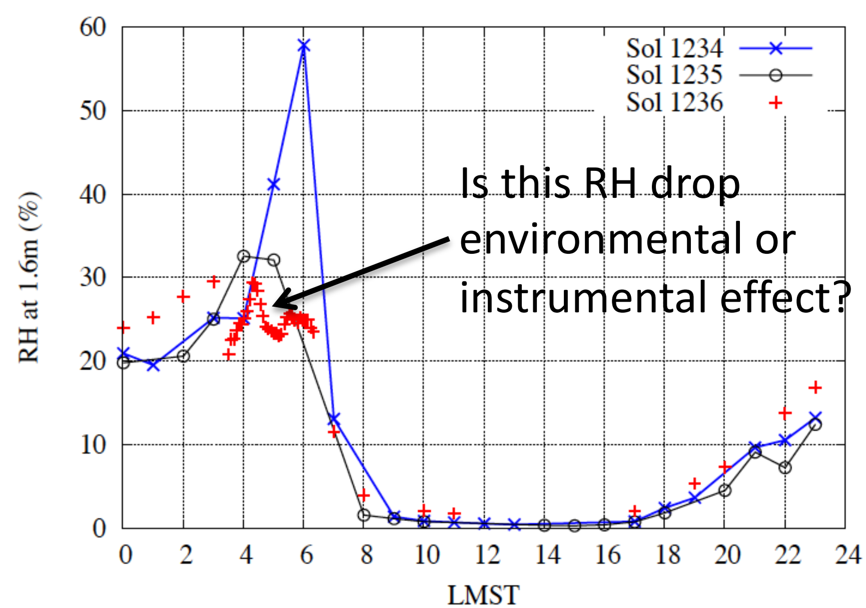
G Martínez, Icarus 2016



On a few sols, like sol 1236, the surface skin temperature T_g crossed the threshold for frost formation, T_f, short before sunrise.

The same threshold was also crossed on Sol 531.

Under study: could brines be forming?
(J Martín-Torres et al. Nature-Geosci. 2014 founc a crossing of the threshold but RH has been corrected downward since then; R Gough 2016)



Near Surface vs total column water vapor

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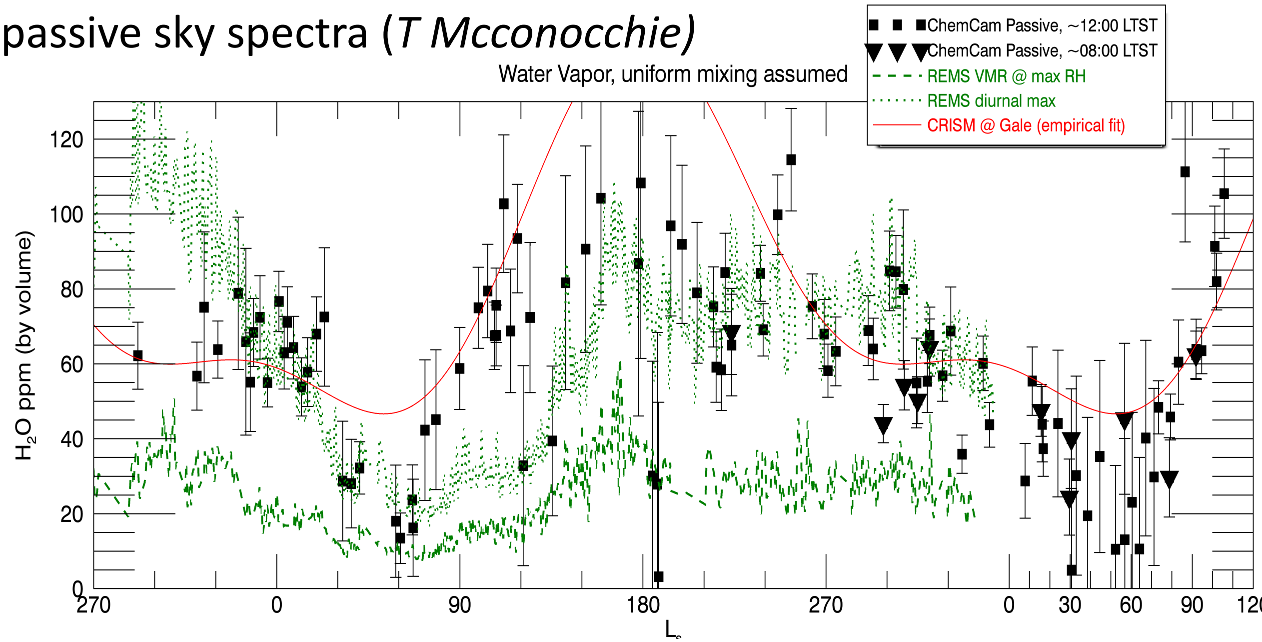
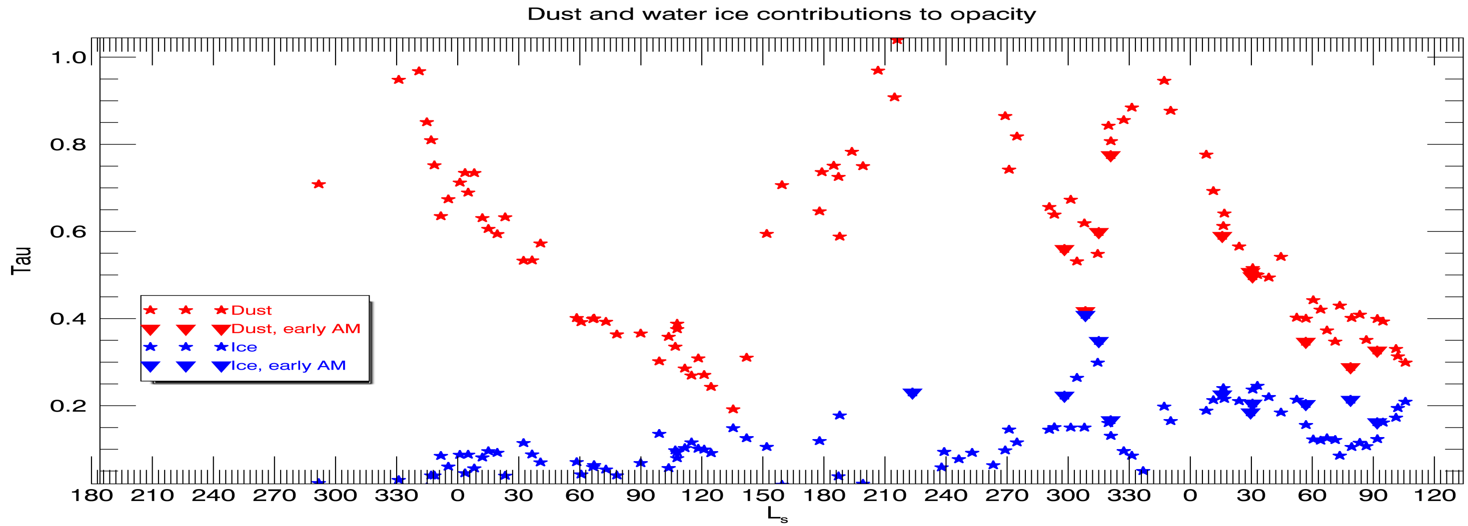
Results from passive sky spectra (*T Mcconocchie)*





Summary

- Longest temperature and second longest pressure records on Mars since Viking.
- Diurnal and annual cycles characterized for different environmental variables.
- Warm equiatiorial latitude.
- Pressure responsive to CO_2 cycle, waves.
- Pressure tidal amplitudes respond to changes in opacity.
- Hydrological cycle characterized at seasonal scales and night time.
- Surface has crossed the thermodynamic threshold for frost formation.
- No dust devils detected.
- Exploring the interrelation of different variables.

Landing site: Aeolis Mons – Gale Crater

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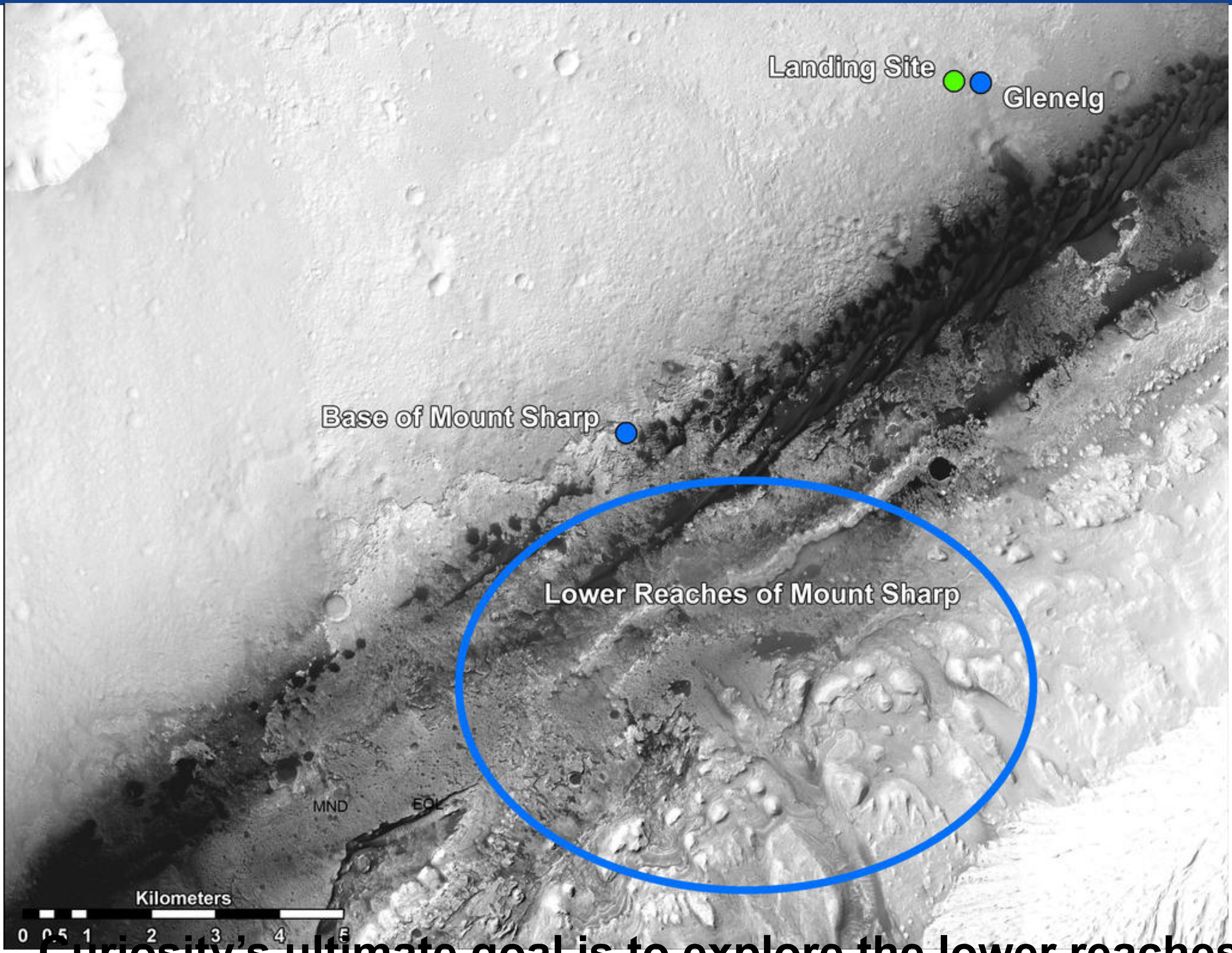

Curiosity's ultimate goal is to explore the lower reaches of the 5-km high Mount Sharp

Landing site: Aeolis Mons – Gale Crater

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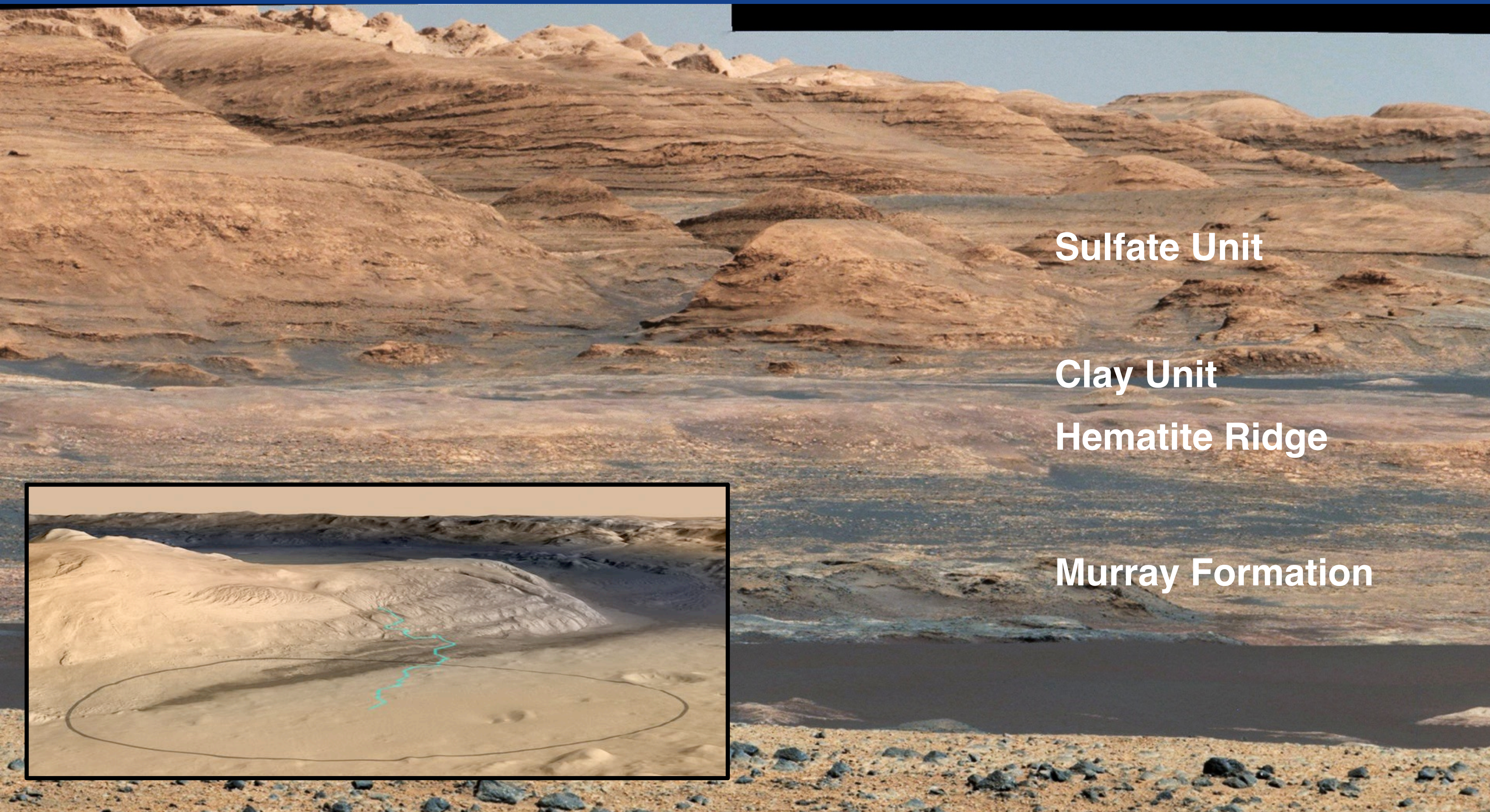

Curiosity's Extended Mission will explore Mt. Sharp, with an emphasis on understanding the subset of habitable environments that preserve organic carbon

Landing site: Aeolis Mons – Gale Crater

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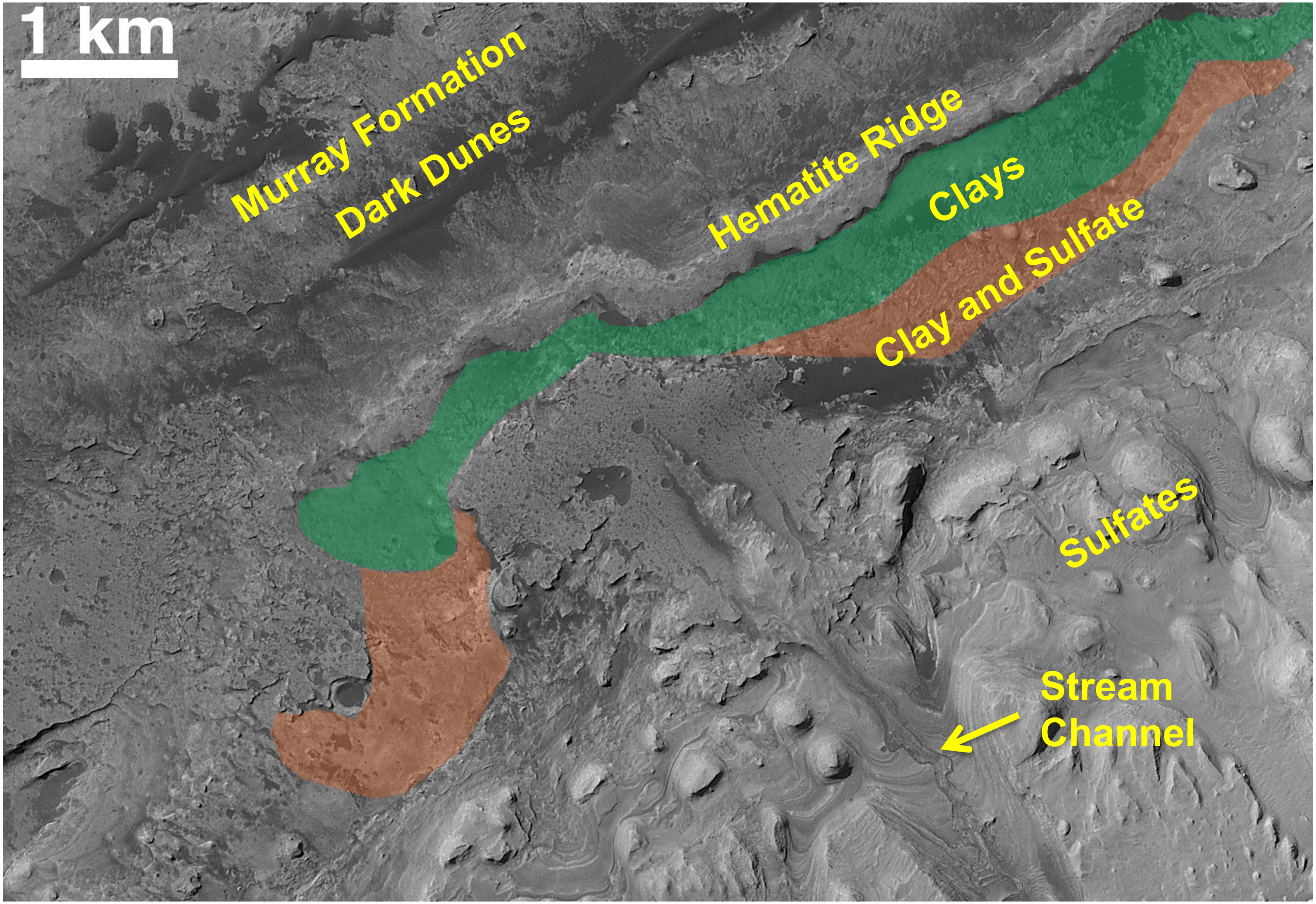

Landing site: Aeolis Mons – Gale Crater

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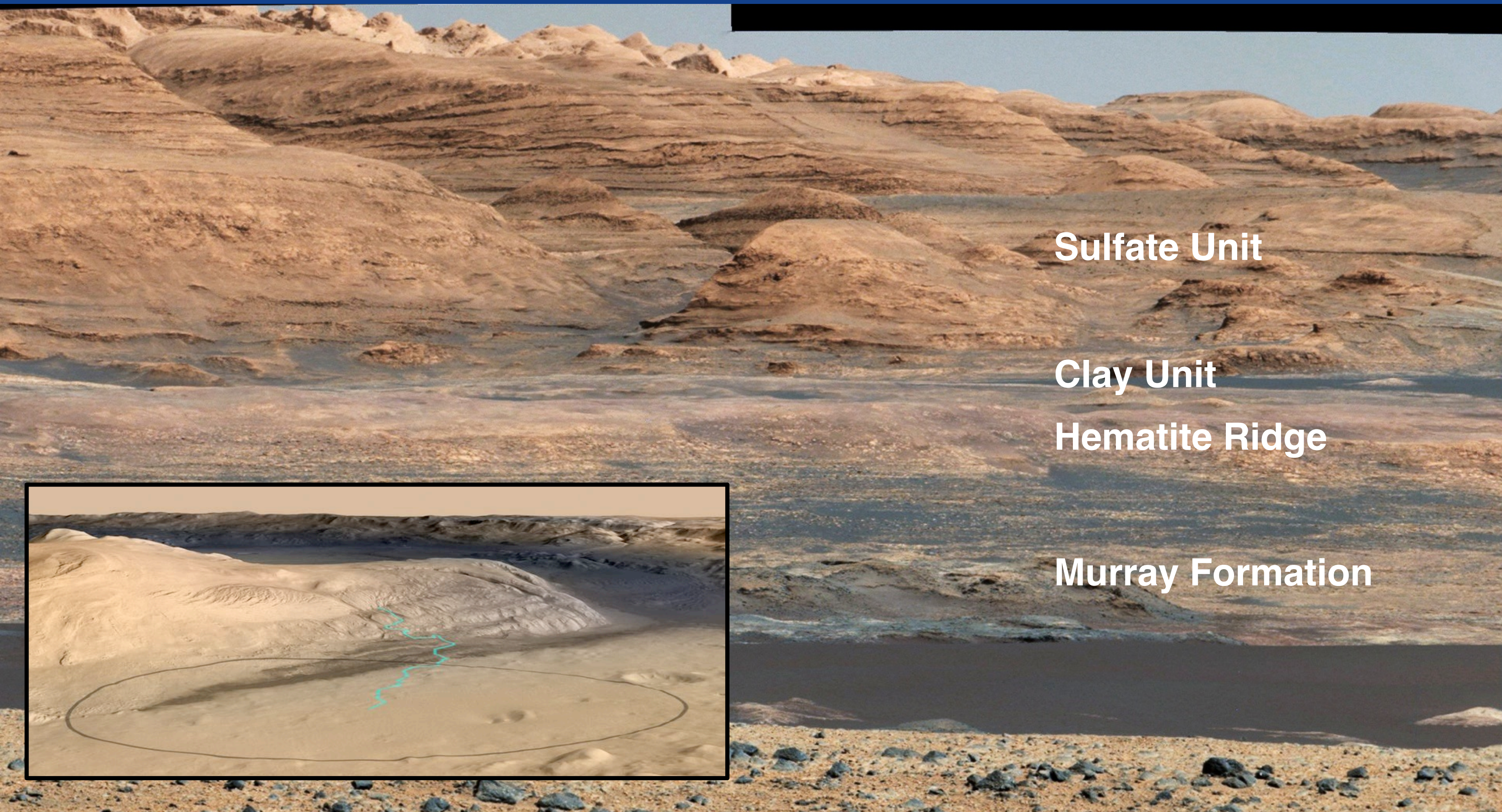

Curiosity's Extended Mission will explore Mt. Sharp, with an emphasis on understanding the subset of habitable environments that preserve organic carbon

Wait, there is more!

Curiosity/M2020 rover size comparison

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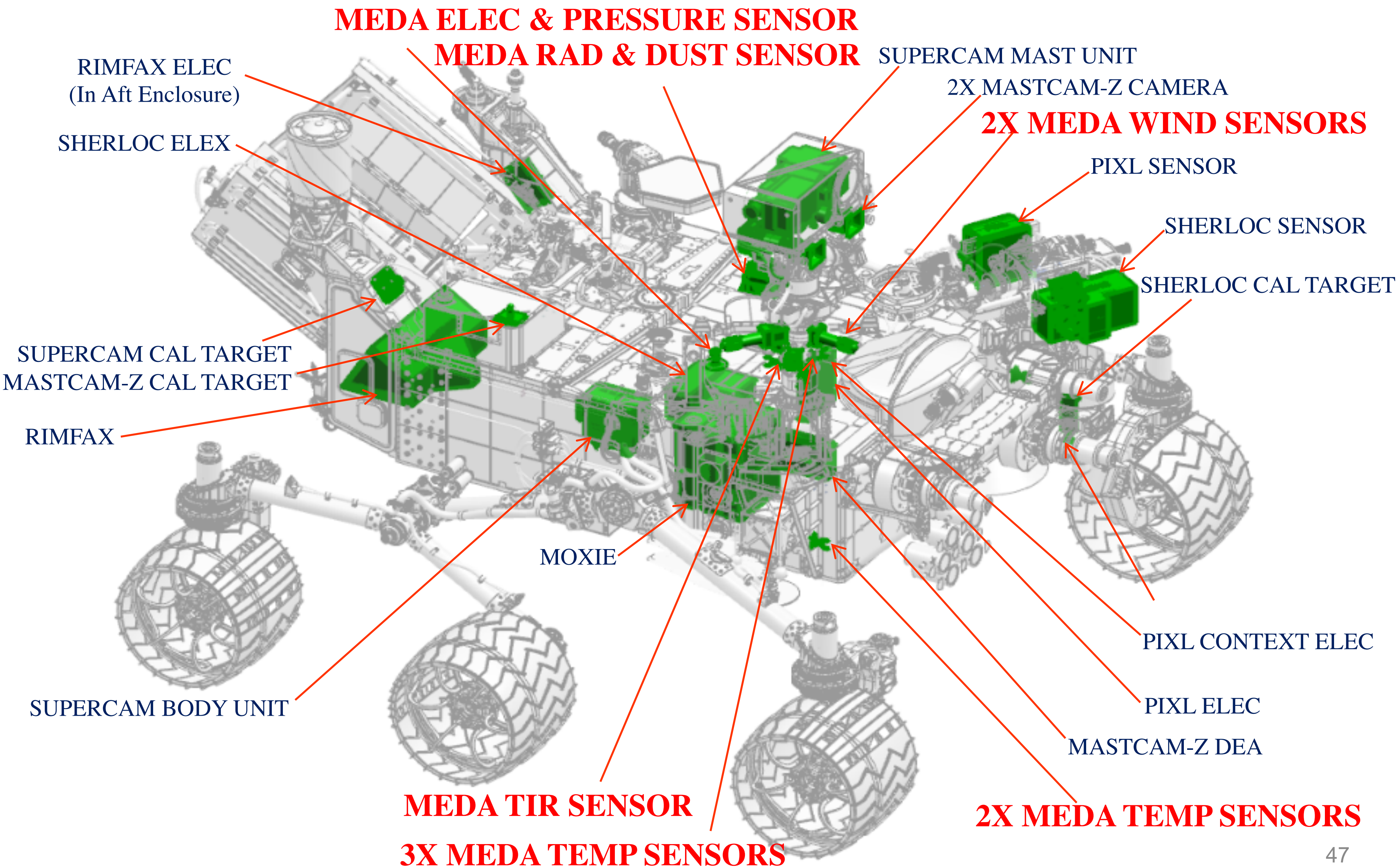
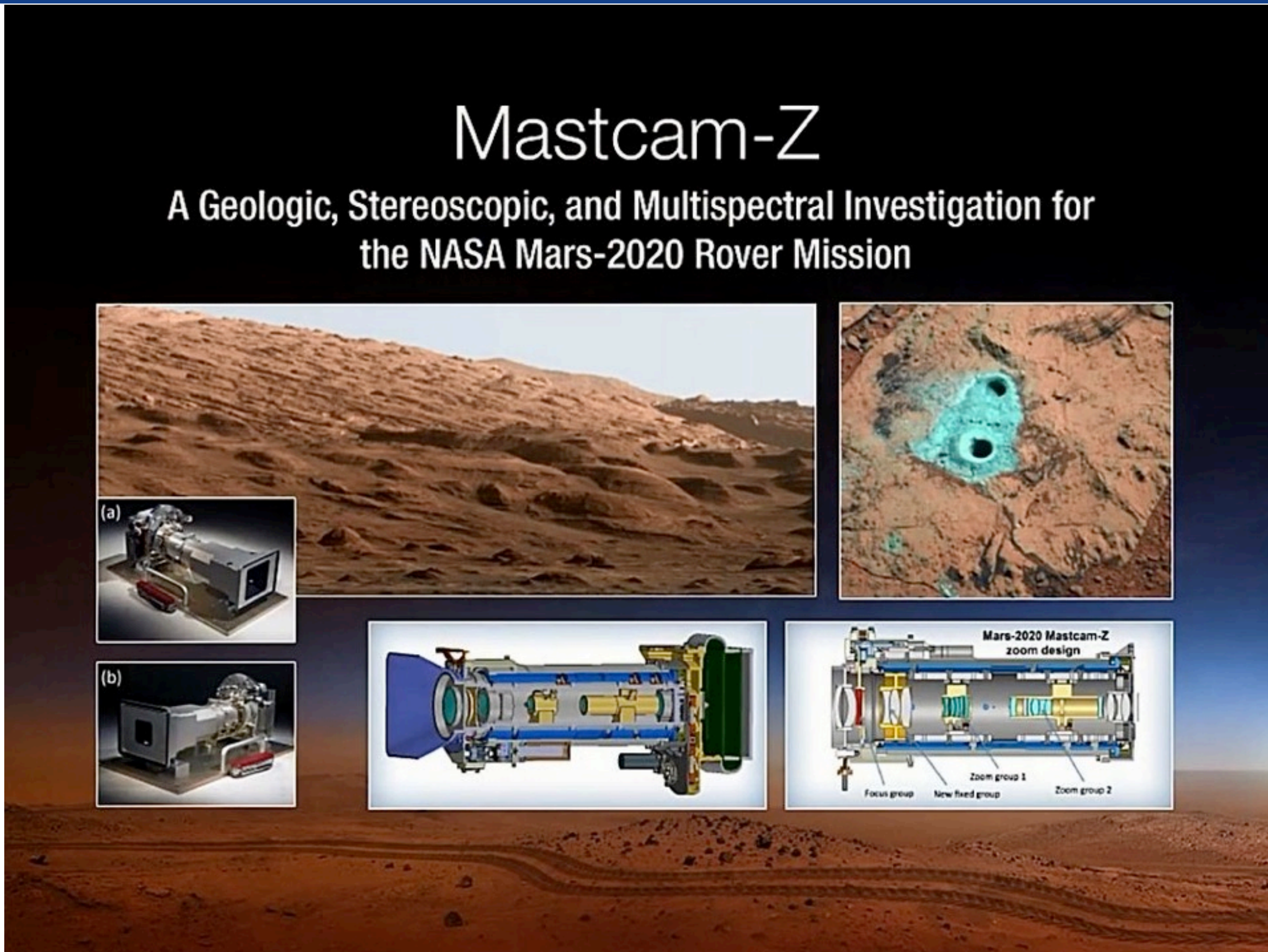
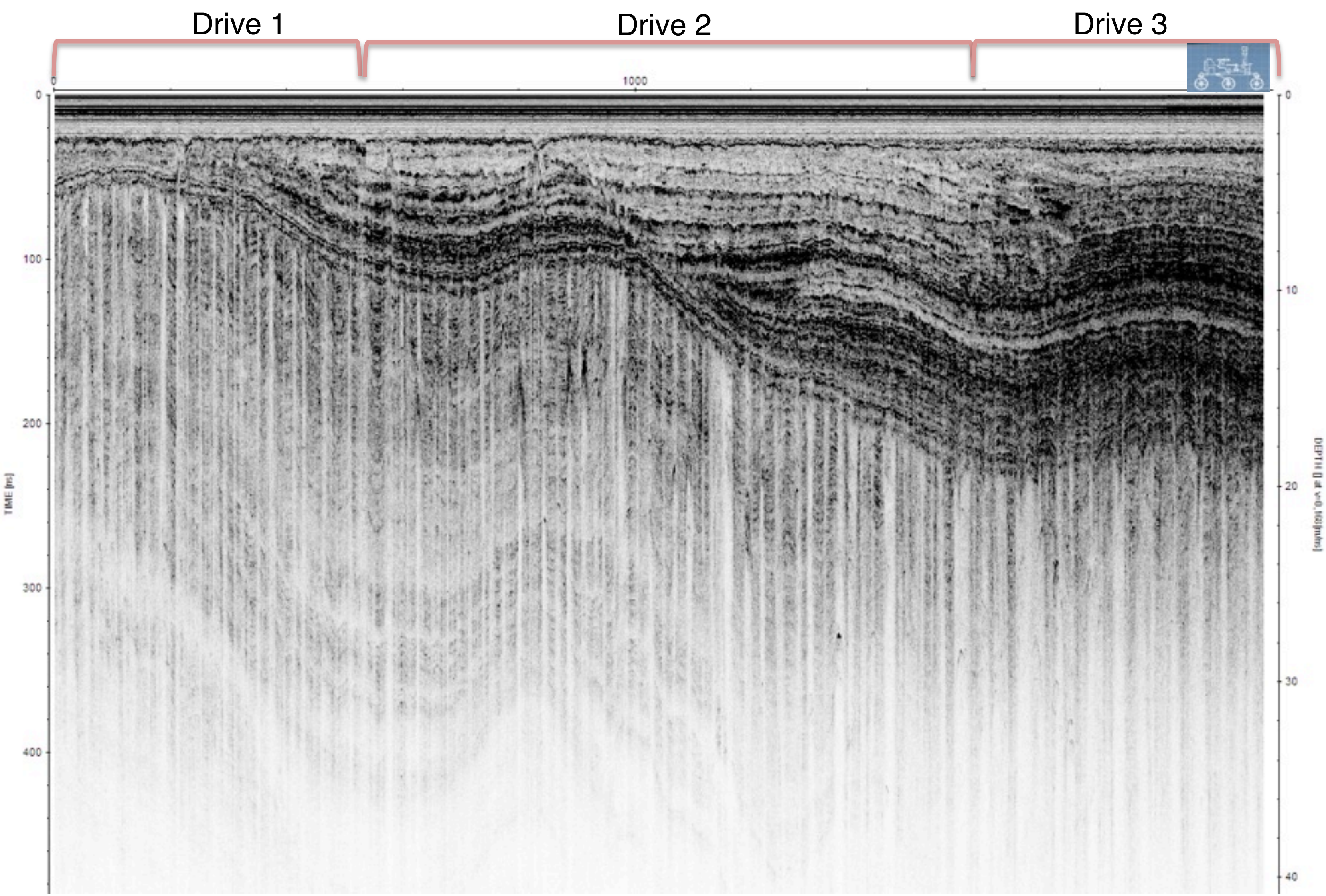
California Institute of Technology



Mastcam-Z


Mastcam-Z
A Geologic, Stereoscopic, and Multispectral Investigation for the NASA Mars-2020 Rover Mission
(a)
(b)
Mars-2020 Mastcam-Z
zoom design
Zoom group 1
Focus group
New fixed group
Zoom group 2

RIMFAX: A view beneath the surface



What next? M2020

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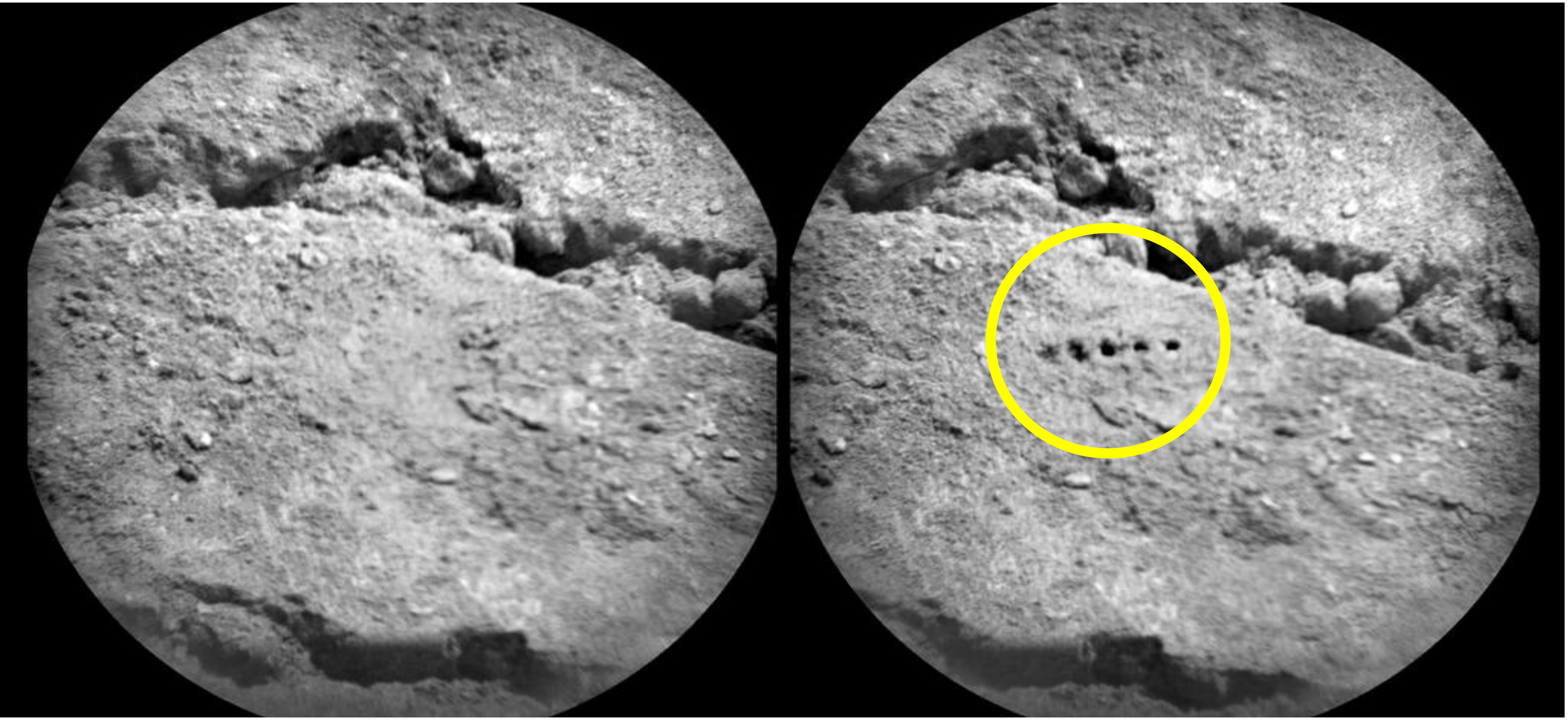
SuperCam: Enhanced ChemCam



ChemCam Target: Beechey (Sol 19)
Power: 1 Gigawatt
5-spot raster, shots per spot: 50

Color RMI, LIBS, Raman, VISIR

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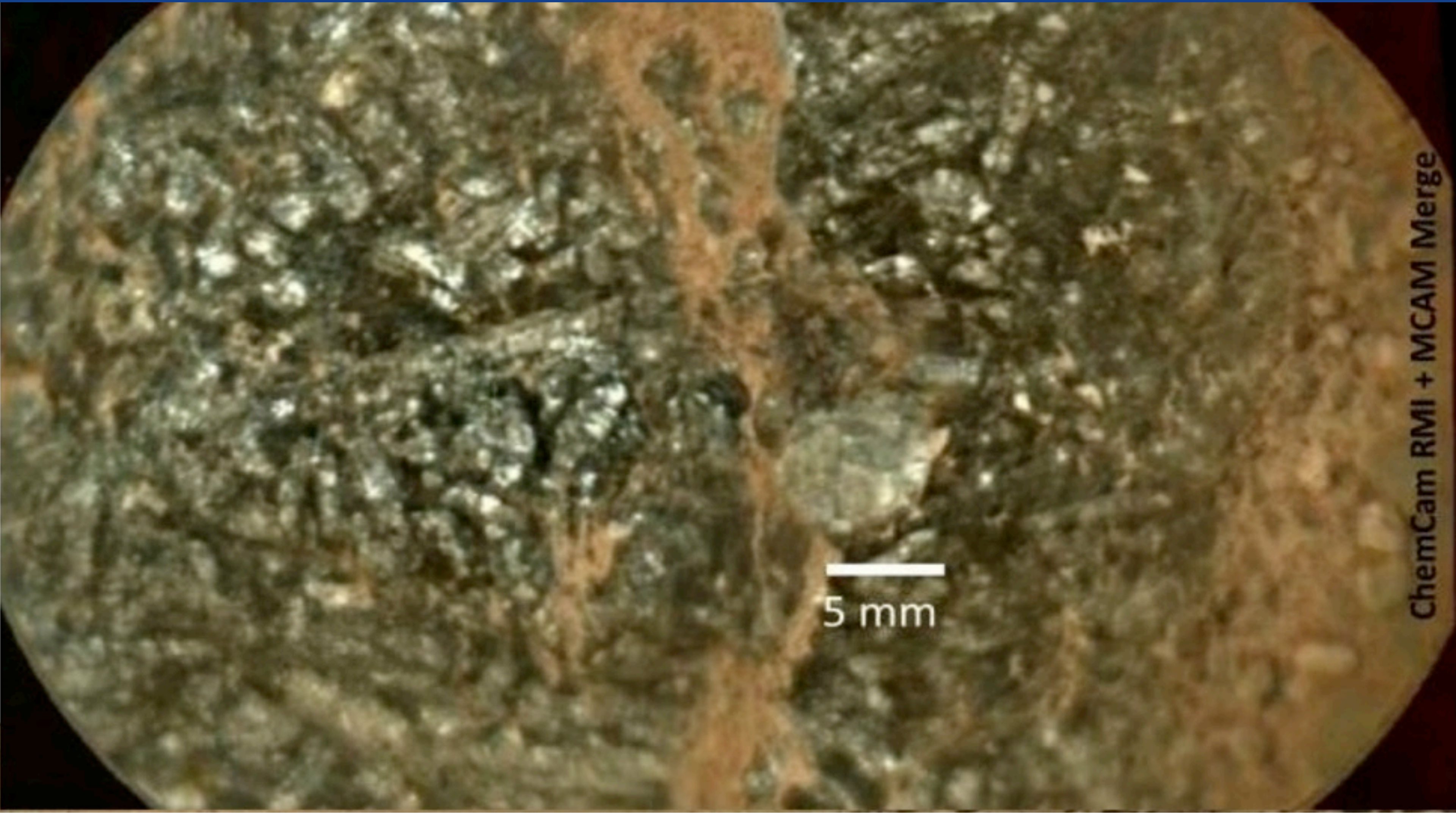
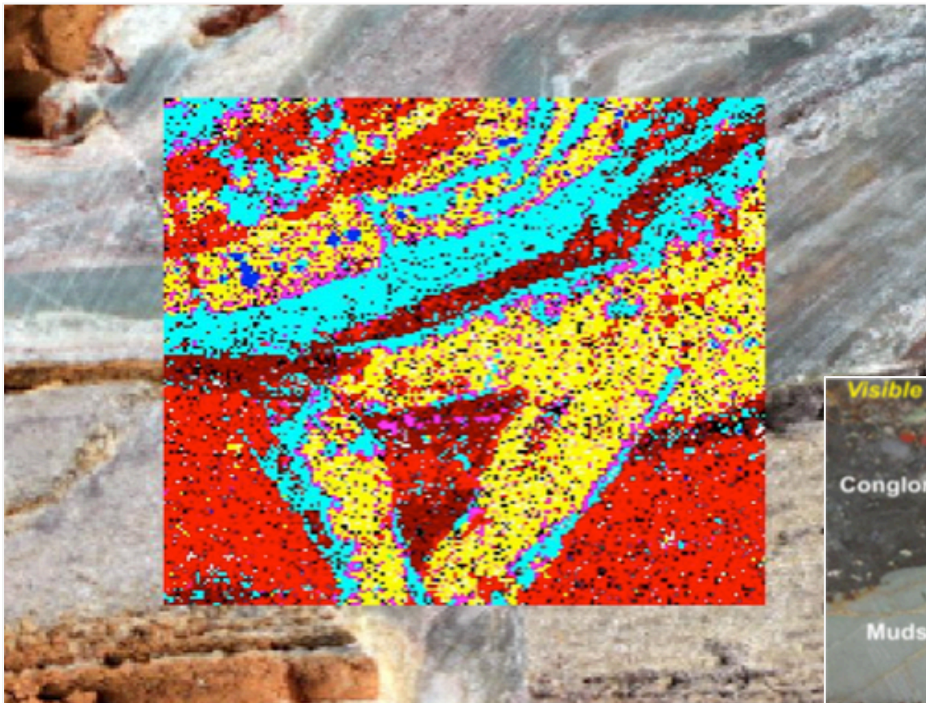
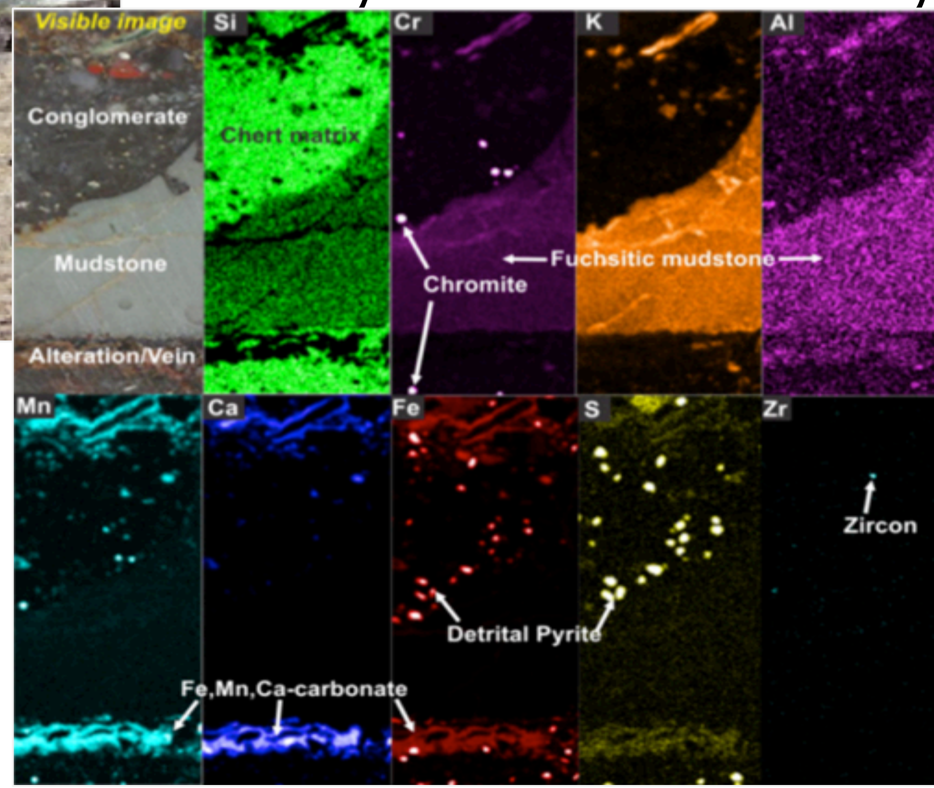


PIXL



PIXL: Planetary Instrument For X-ray Lithochemistry

micro x-ray fluorescence
for elemental mapping
with sub-mm resolution



SHERLOC

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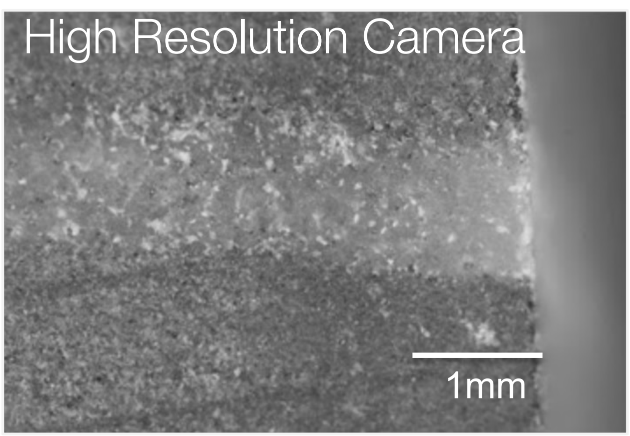
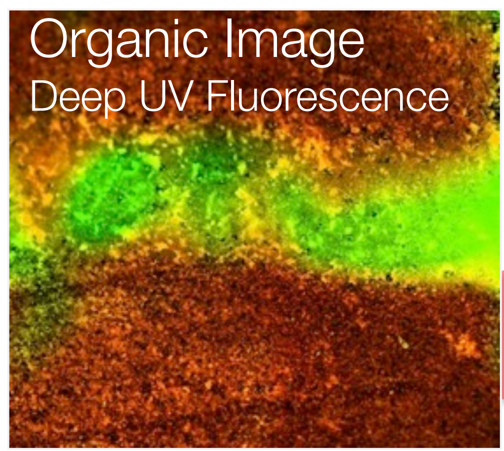
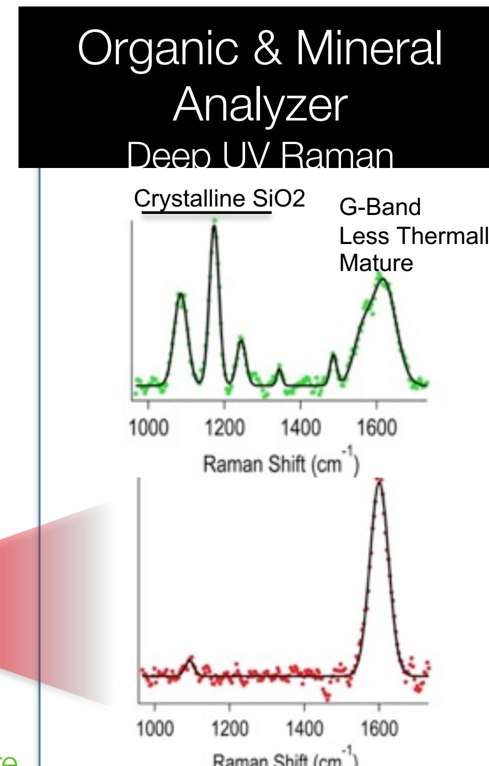
SHERLOC: Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals

SHERLOC's view through WATSON







More Mature Less Mature
Organic Maturity

MEDA

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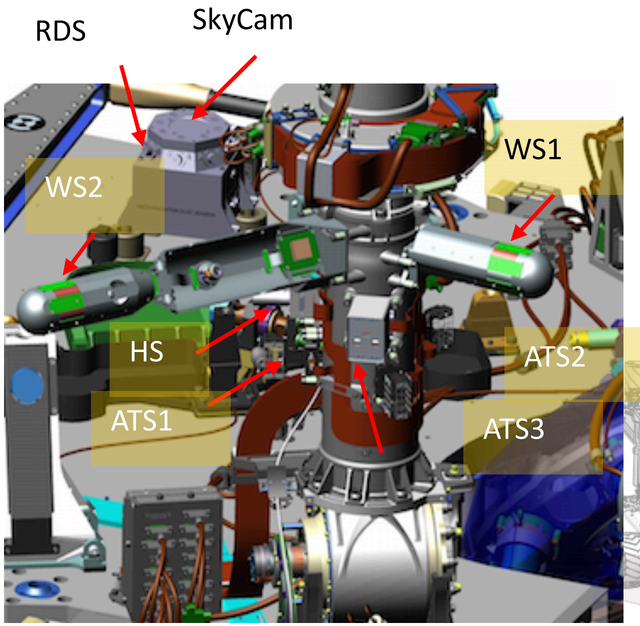
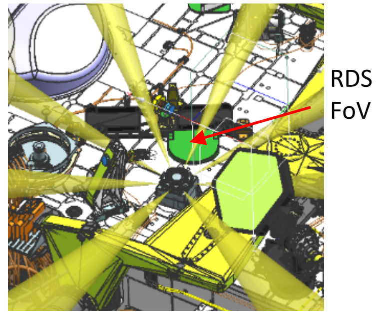
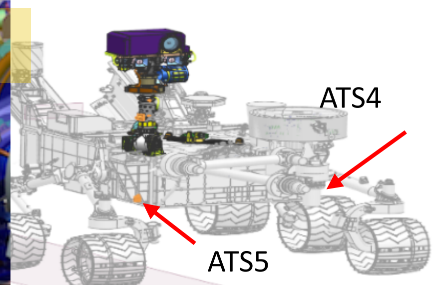
California Institute of Technology



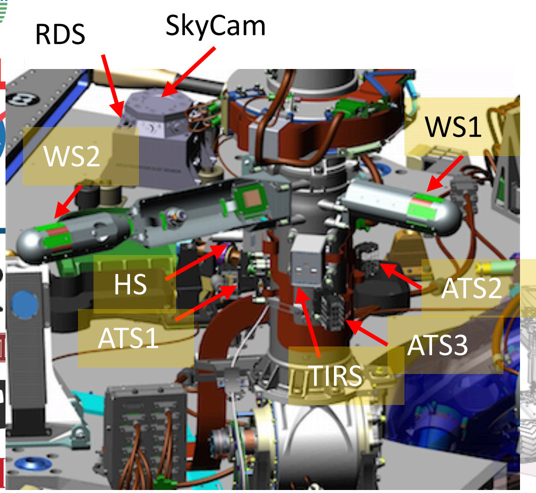


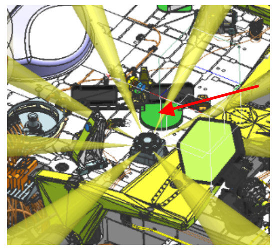


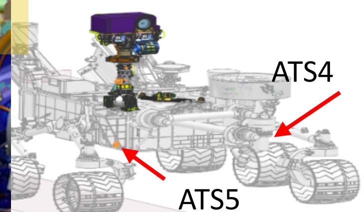
INSTRUMENT DESCRIPTION:

- Upgraded sensor package and electronics unit serve as follow-on to REMS
  - ICU and PS on RAMP
  - 170-mm fixed and 396-mm switch-blade WS on RSM
  - 5 ATSs (3 on RSM, 2 on rover body)
  - Thermal IR Sensor (TIRS), on RSM
  - Humidity Sensor (HS), on RSM
  - Radiation and Dust Sensor, including SkyCam, to image atmospheric dust opacities & scattering, on rover deck
- Various power states can meet needs of all sol types
- 5.2 kg mass, with current protection plans

MEDA Project Objectives: Instrument Overview







INSTRUMENT DESCRIPTION (updates in red):

- Upgraded sensor package and electronics unit serve as follow-on to REMS
  - ICU and PS on RAMP
  - 170-mm fixed and 396-mm switch-blade WS on RSM
  - 5 ATSs (3 on RSM, 2 on rover body)
  - Thermal IR Sensor (TIRS), on RSM
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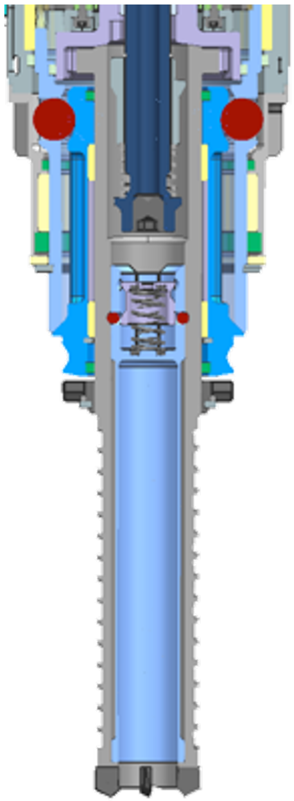
  - Radiation and Dust Sensor, including SkyCam, to image atmospheric dust opacities & scattering, on rover deck
- Various power states can meet needs of all sol types
- 5.2 kg mass, with current protection plans

Complete

Successfully passed

Returned Sample Science (RSS)

Jet Propulsion Laboratory
California Institute of Technology



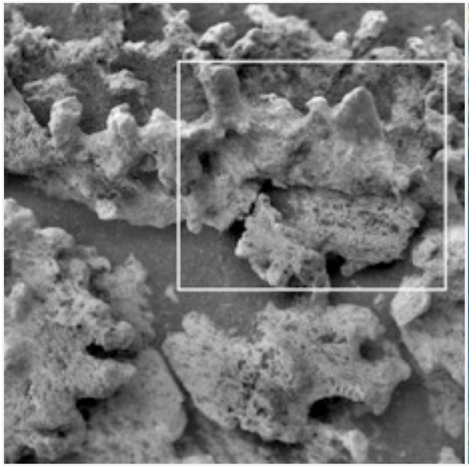
A NEW INVESTIGATION FOR MARS 2020:

- **Returned Sample Science Board** (RSSB) chartered by NASA HQ
- Representation in the Project Science Group (PSG)
- Advisory role to Mars 2020 Project Science on issues related to sample integrity, e.g. sample temperature, blank strategy

- RSS Investigation Scientist at JPL interfacing between project science, engineering/flight system, RSSB, and science team

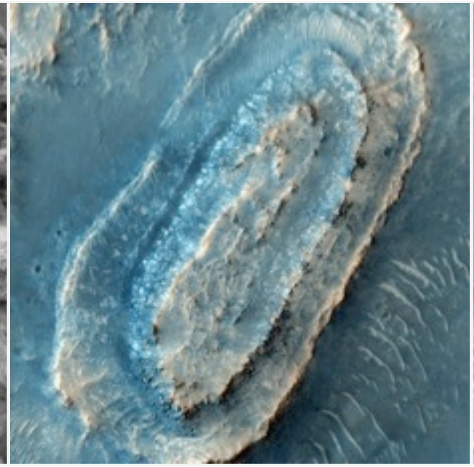
M2020 candidate landing sites

Jet Propulsion Laboratory
California Institute of Technology



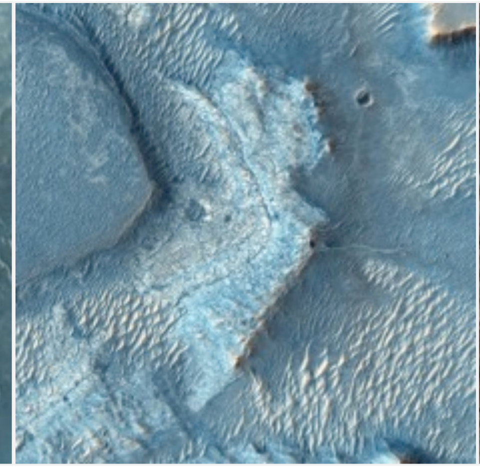
COLUMBIA HILLS

- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin and Hesperian lava flow
- Potential biosignatures identified
- Previously explored by MER



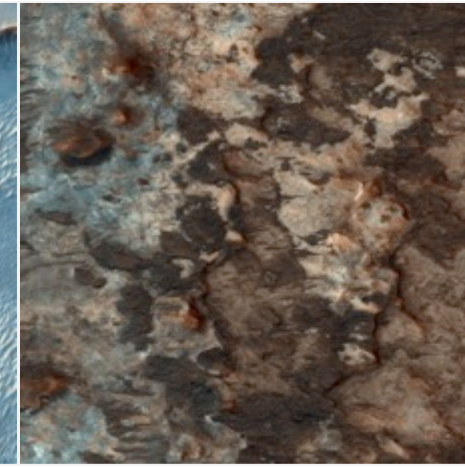
NE SYRTIS

- Extremely ancient igneous, hydrothermal, and sedimentary environments
- High mineralogic diversity with phyllosilicates, sulfates, carbonates, olivine
- Serpentinization and subsurface habitability?



NILI FOSSAE

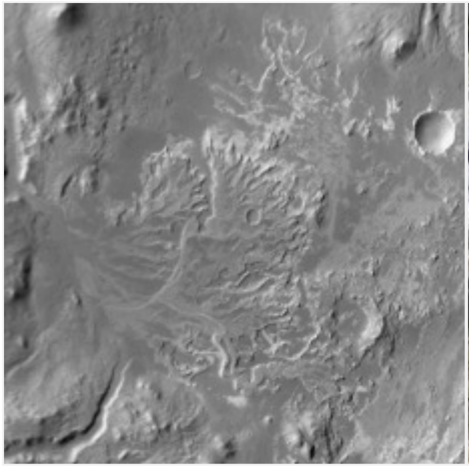
- Extremely ancient igneous, hydrothermal, and sedimentary environments
- Crustal phyllosilicates, carbonates, olivine, Hargreaves ejecta
- Serpentinization and subsurface habitability?



MAWRTH VALLIS

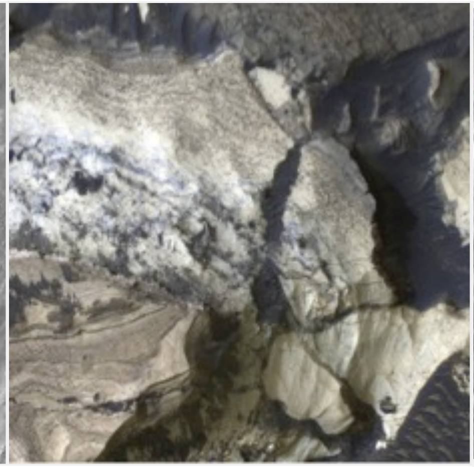
- Abundant and diverse phyllosilicates may preserve organics
- Groundwater-fed system with pedogenesis or in place alteration?

M2020 candidate landing sites



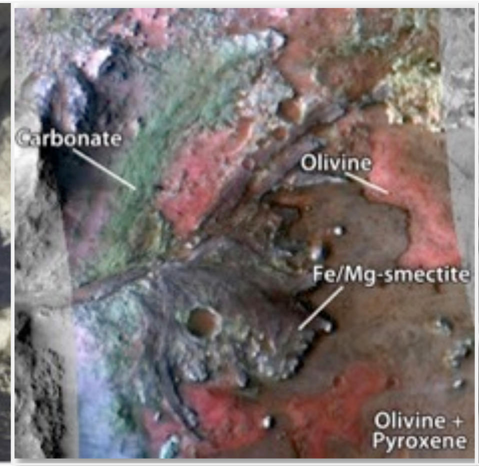
EBERSWALDE

- Deltaic/lacustrine deposition with megabreccia
- Evidence for hydrous minerals from CRISM
- Extensively mapped for MSL



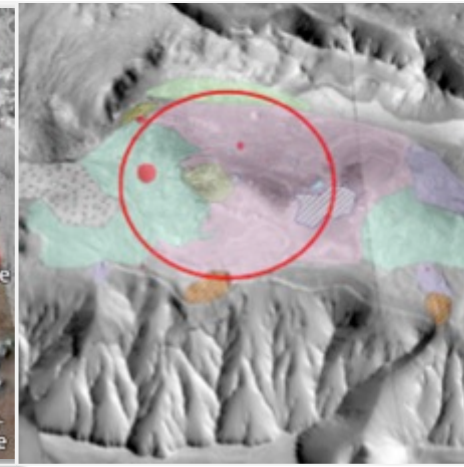
HOLDEN

- Deltaic/lacustrine deposition with megabreccia
- Evidence for hydrous minerals from CRISM
- Extensively mapped for MSL



JEZERO

- Deltaic/lacustrine deposition with Hesperian lava flow and hydrous alteration
- Evidence for hydrous minerals from CRISM, *including carbonates*



SW MELAS

- Deltaic/lacustrine deposition wtihin Valles Marineris
- Evidence for hydrous minerals from CRISM, *including hydrated silica*